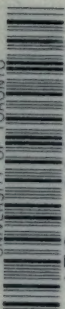


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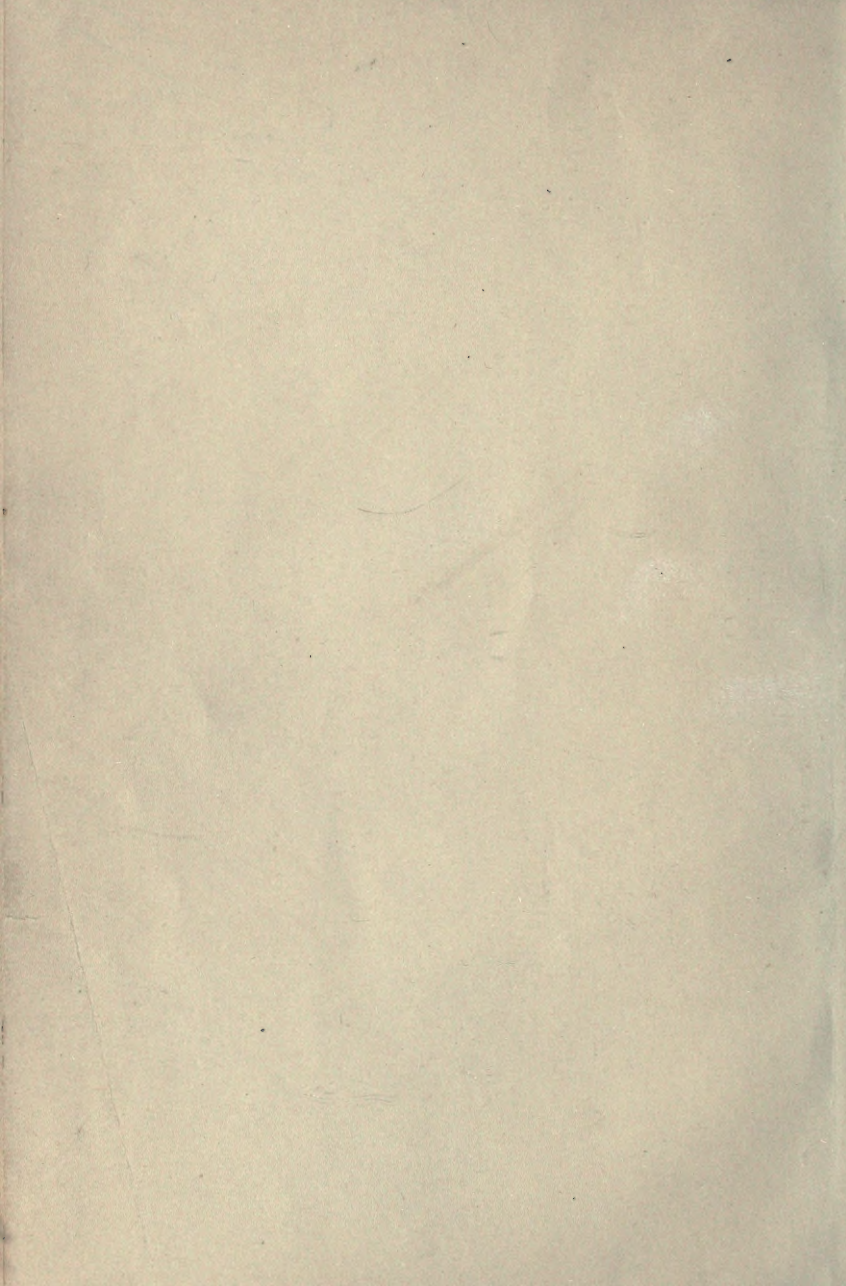
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ASSAYING

IN

THREE PARTS

PART 1st—GOLD AND SILVER ORES; PART 2d—
GOLD AND SILVER BULLION; PART
3d—LEAD, COPPER, TIN,
MERCURY, ETC.

By C. H. AARON, METALLURGIST,

AUTHOR OF

"TESTING AND WORKING SILVER ORES," "LEACHING GOLD AND SILVER ORES."

PART I.

SIXTH EDITION.

PUBLISHED AND SOLD BY
THE MINING AND SCIENTIFIC PRESS,
OF SAN FRANCISCO

1906.

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TO
The Mining and Scientific Press,
OF
SAN FRANCISCO, CAL.

THE STEADFAST FRIEND OF TRUTH AND
PROGRESS—AN HONEST PAPER—

THIS BOOK IS RESPECTFULLY DEDICATED
BY THE AUTHOR.

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PREFACE TO THE THIRD EDITION.

IN a prefatory note to the second edition of this work, its author, the late Charles H. Aaron, says:—

“In preparing this second edition I have not been deterred from making alterations, and (as I hope) improvements, by any fears as to the impression which may be produced by the tacit admission that the first was not all that it might have been. Of those who have taken that as their guide, I have yet to hear of one who has been led astray; nevertheless, I candidly think that all such may now be gainers by laying that aside and taking this.”

To the edition thus introduced, Mr. Aaron applied the same critical habit which had discovered and corrected many faults in the earlier work. Page by page again and again he went over the book, adding and retouching as new observation and experience developed new knowledge, and as riper judgment enabled him to make the meaning clearer and the instruction more definite and complete. A copy of the second edition, with scarcely a page untouched by his discriminating pen, was among Mr. Aaron's effects, and is now in the hands of the publishers. It has been made the basis of the general revision herewith presented, every correction and addition of the author being faithfully reproduced.

This third edition, therefore, represents the matured work of the author, and we may say with candor, as he said in a former instance, that those who have profitably used the earlier edition may now be gainers by laying it aside and taking this.

THE PUBLISHERS.

PREFACE TO THE FOURTH EDITION.

THE standard character of this work and the steady demand therefor, justify the publishers in issuing a fourth edition, revised and further brought up to date, with the belief that in the progressive science of which it treats the technical reader will find sufficient of value to justify its profitable use.

THE PUBLISHERS.

San Francisco, Jan. 1, 1900.

PREFACE TO THE FIFTH EDITION.

THE advance in the present state of the art, and consequent present requirements, have made necessary revision and rewriting of this work throughout, and the fifth edition is presented in the hope that it will be accorded the same measure of profitable approval accorded the earlier editions of this standard work.

THE PUBLISHERS.

San Francisco, March 25, 1904.

PREFACE TO THE SIXTH EDITION.

The few remaining copies of the fifth edition were destroyed in the San Francisco earthquake fire. The subsequent demand for this practical work has emphasized its usefulness and has justified a new edition. This has been thoroughly revised by a competent assayer who has incorporated in it the results of years of teaching. The book, while retaining its former simplicity of style, is technically accurate in its description of the most approved methods of assaying.

THE PUBLISHERS.

San Francisco, December 1, 1906.

INTRODUCTION.

ALL substances in nature are either simple or compound. A simple substance or body is one from which nothing different from itself can be extracted. There are about eighty simple substances known. They are called elements.

The elements have a tendency to combine one with another, forming compounds; this tendency is called affinity. The strength of the affinities of different elements differs. The strength of the affinity of any one element for any other differs under different conditions of temperature, pressure, electricity, etc.

Elements are known to be capable of assuming the solid or the gaseous state; most of them, also the intermediate condition of a liquid, the assuming of these different conditions by the same substance being dependent on temperature and pressure.

The elements may be *mixed* in *any* proportions, but they *combine* only in *fixed* proportions. When elements combine, they form a substance which has different properties from those of the components. Two or more solids may combine to form a liquid or a gas; two or more liquids or gases may form a solid, etc. A knowledge of the proportions in which bodies combine, and of the conditions which determine their combination and dissociation, forms the basis of chemistry.

All the metals are elements; their mixture by fusion forms alloys. Hydrogen, oxygen, nitrogen, chlorine, bromine, iodine, carbon, sulphur, selenium, phosphorus, boron, silicon, are elements which, with the metals, enter

into the composition of the ores, fluxes, etc., which come under the notice of the assayer.

The fact that the elements combine only in fixed proportions is the reason why a certain quantity of combustible matter produces only a certain quantity of lead from litharge in an assay. The element lead (a metal) combined with the element oxygen (a gas) in the proportion of 103.56 parts by weight of lead to 8 parts by weight of oxygen, forms 111.56 parts of litharge. Lead combines with oxygen, under certain conditions, in two other proportions, but the resulting compounds are not litharge, and the proportions are definite and unchangeable in each, combining spontaneously under proper conditions, and any excess of either element remaining separate.

The element carbon also combines with oxygen, 6 parts of the former and 16 of the latter, forming 22 parts of the gas commonly called carbonic acid gas or carbon dioxide. Under the action of heat, the affinity of carbon for oxygen is greater than the affinity of lead for oxygen; hence if litharge and carbon are heated together, the carbon takes oxygen from the litharge and sets lead free. But this action can only take place between definite proportions of the substances. If twice 111.56 grams of litharge, containing 16 grams of oxygen, be heated together with 6 grams of carbon, the carbon takes all the oxygen, forming 22 grams of carbonic acid gas, and the whole of the lead is set free; but if more litharge had been present, that additional portion would have remained unchanged. From this we see that 6 grams of carbon reduce 223.12 grams litharge, setting free 207.12

grams of lead, or 1 gram of carbon produces 34.52 grams of lead from litharge.

Hydrogen, sulphur, iron, and many other substances take oxygen from litharge under heat, in different but fixed proportions for each. Charcoal is slightly impure carbon, and 1 gram liberates only about 30 grams of lead from a corresponding quantity of litharge. Flour contains both carbon and hydrogen, but as it also contains oxygen and nitrogen, it is less efficient, weight for weight, than charcoal as a reducing agent; 1 gram liberates about 15 grams of lead; it is preferable to charcoal for assaying, because it is cleanly and in fine powder.

Niter consists of nitrogen, oxygen, and potassium. When heated, it gives off a part of its oxygen, and if lead is present litharge is formed, the quantity of lead so transformed depending on the quantity of the nitre, in accordance with the law of definite proportions; if sulphur or carbon be also present, the oxygen combines with that, because the affinity is stronger than for lead.

Compounds can combine with other compounds, forming new compounds. The alkaline carbonates used in assaying are compounds of the metal elements sodium or potassium with oxygen and carbon dioxide. Quartz (silica) is a compound of silicon with oxygen. When quartz is heated in contact with an alkali carbonate, the latter is decomposed, not into its elements, but into carbonic dioxide, which escapes with effervescence, and sodium or potassium oxide, which combines with the quartz—a compound with a compound—forming glass; thus quartz, which is not fusible at any common furnace heat, is converted into an easily fusible substance.

One-fifth part of the air consists of oxygen, the other

four-fifths of nitrogen; they are only mixed, not combined. Melted lead has a strong affinity for oxygen, which it takes readily from the air in such proportion as to form litharge; gold and silver at the heat of melted lead do not combine with oxygen; hence, when an alloy of lead, gold, and silver is melted in air, the lead oxidizes, the gold and silver do not; if the litharge is removed as it is formed, all the lead is finally separated from the precious metals; this is the philosophy of cupellation.

When silver is placed in nitric acid, it develops an affinity for a compound of nitrogen and oxygen which exists in the acid; gold does not; hence, when an alloy of gold and silver is boiled in nitric acid, the silver forms a compound known as nitrate of silver, which is soluble in water, and if the acid is somewhat dilute, all of the silver is dissolved, while the gold remains. From the law of combination in definite proportions it is necessary that the acid be present in sufficient quantity, otherwise a portion of the silver remains unaltered; if more than the requisite quantity be used, the excess of acid remains unchanged. In practise, the alloy must contain at least twice as much silver as gold, otherwise the insoluble gold so envelops the silver as to protect it from the action of the acid, except superficially.

Thus the *art* of assaying is dependent on the laws of chemistry, and, although it may be practised with considerable success, it can not be properly understood unless those laws are studied.

An *assay* is an operation performed on a known quantity of matter for the purpose of ascertaining how much of a certain substance that quantity of that kind of matter contains. A *test* is an operation performed on an

indefinite quantity of matter in order to ascertain the character of that matter, or to determine the presence or absence of some particular substance.* Thus, to test a piece of rock for silver is merely to try whether it contains any silver or not; to assay it for silver is to find out how much silver is contained in a weighed quantity, as an ounce or a half ounce, and thence, by calculation, in a ton of such rock. Testing may often precede assaying with great advantage, because it enables us to know what kind of matter we have to deal with, and thus to adapt our method so as to insure a correct assay; or it may show us that an assay would be useless because of the absence of the substance sought, or of its presence in such minute quantity only as to be practically worthless.

To avoid confusion hereafter, it is as well to mention that not only the act of assaying, but also the definite quantity of matter operated on, is called an *assay*. Also, a *test* is either the act of testing, the thing tested, or the agent by means of which a test is made.

Assays and tests are of two principal classes, the dry, or fire, and the wet, or humid, assay or test. In the dry way, the substance under examination is usually melted by heat, with the addition of such substances as may be necessary to produce fluidity and to separate the particular substance sought from the other components. The added substances are called fluxes, reducers, oxidizers, desulphurizers, etc., according to their functions in the operation. In the wet way, the substance, if solid, is acted on by means of liquid solvents, such as

*These definitions are in accordance with technical usage rather than with etymology.

acids, etc., which convert it, wholly or in part, into a liquid. By the addition of "*reagents*" to the liquid, the substance sought is separated, or its presence, and in assays its quantity is determined by the occurrence of some appreciable phenomenon, such as the production of a precipitate or of a color. For example, a portion of impure bullion is dissolved in nitric acid, and a solution of common salt is added; the formation of a white precipitate indicates the *presence* of silver; this is a test.* If the portion of bullion be weighed, and the exact quantity of salt required for the complete precipitation of the silver be also ascertained, the proportion of silver in the bullion is easily deduced; this is an assay. Again, a substance supposed to contain copper is dissolved in acid, and ammonia is added; the production of a blue color indicates that copper is present, and if the portion of the substance be weighed before being dissolved, we can ascertain how much copper it contains by noting how much cyanide of potassium it takes to destroy the color.*

Silver ores are assayed in the dry way, gold ores by a combination of the dry and the wet way. By ores is here meant all mineral, rock, or earth containing the metal sought in small particles, or in chemical combination. Silver ores very frequently contain gold, and gold rarely occurs quite free from silver. The ore is ground to powder, weighed, and melted in an earthen vessel (*crucible or scorifier*) with fluxes including lead in some

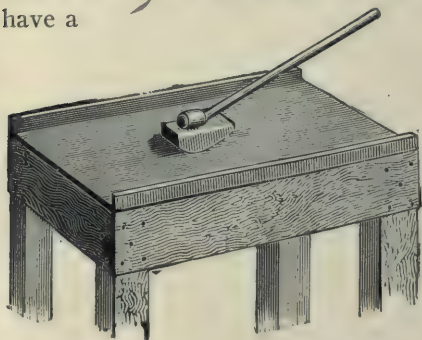
*This must only be taken as an illustration. Lead or mercury in certain circumstances, would also give a white precipitate.

*Nickel also gives a blue color, and, if there is any question, must be distinguished by other tests.

form; a glassy mass (*slag*) and a lump of lead (*button*) result. The lead contains the precious metal, and is melted on a porous support (*cupel*) in an oven (*muffle*), converted into litharge and absorbed by the support. The gold and silver remain in the form of a *bead* on the support; the two are parted by boiling the bead in nitric acid. The following described implements and material are used, which can be obtained from any dealer in chemists' and assayers' supplies.

IMPLEMENTS.

IRON MORTAR AND PESTLE FOR PULVERIZING ORES.
—Size and price of each: $\frac{1}{2}$ pint, 75 cents; 1 pint, \$1.00; 1 quart, \$1.25; $\frac{1}{2}$ gallon, \$1.75; 1 gallon, \$2.50; $1\frac{1}{2}$ gallons, \$3.00; 2 gallons, \$4.75; 3 gallons, \$7.50. It is convenient to have several sizes, but the third or fourth size will answer all purposes. It is also convenient to have a



BUCKINGBOARD WITH MULLER, 20x24 inches, made of cast iron; price, \$13, or a rectangular grinding-plate, 7x28 inches, with trunnions and bearings at side, to discharge the ground ore into a pan by tilting the plate; price, \$6.50.

BUCK'S PATENT AMALGAM MORTAR may replace plate and muller for grinding. Is also good for the assay by amalgamation. Diameter, $8\frac{1}{2}$ inches; weight of mortar and muller, 68 pounds; price, \$7.50.





POWER CRUSHER AND GRINDER. — Where many assays have to be made on short notice, a crusher and grinder run by power will be found almost indispensable. Very good types of these machines are shown in the cuts. The crusher costs \$43.00, and the grinder \$85.00.

WEDGEWOOD

MORTAR. — Price

and diameter of

each: $3\frac{3}{4}$ inches,

75 cents; $4\frac{1}{2}$

inches, 90 cents;

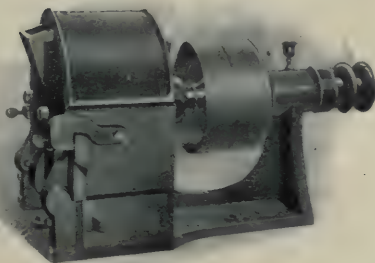
$5\frac{1}{4}$ inches, \$1.00;

6 inches, \$1.25;

$6\frac{3}{4}$ inches, \$1.50;

$7\frac{1}{2}$ inches, \$1.75;

$8\frac{3}{8}$ inches, \$2.50. Chiefly used for powdering fluxes and mixing the assays. One of these is sufficient, and, in case of need, may be dispensed with.



SIEVES.—These should be eight in number, respectively, of 2, 4, 10, 20, 40, 60, 80, and 100 meshes to the running inch. They are formed of brass wire cloth stretched on circular rims of wood or tin, the latter being preferable. The 2 and 4 mesh sieves should be about 12 inches in

diameter, respectively, the others about 8 inches in diameter. It is very convenient to have sieves which will fit about two-thirds of the way into the sample pans (see below).

SAMPLE PANS.—These are similar to cake-tins. There should be two sizes, about 8 and 5 inches in diameter respectively. The large diameter of the 8-inch pan should be slightly larger than that of the 8-inch sieve noted above.

SPATULAS, ETC.—Two apothecaries' spatulas, the one about 10, the other about 6, inches long; and a few large and small common spoons should be provided.

PULP SCALES.—These scales cost \$11, will carry two ounces, and are sensitive to one milligram when new. A set of assay ton weights from 2 A. T. to 1-20 of an A. T. are very necessary, and cost \$6.00; also a set of weights from 50 grams to 1 gram, costs \$5.00, or a set from 50 grams to 1-10th of a milligram, including all the weights necessary for this scale and the finer assay balance to be described hereafter, may be bought for \$12.00. Grain weights can be had if desired. The best weights should always be bought.

In addition to the pulp scales, an ordinary grocer's scales will be found useful for weighing out large samples of ore, fluxes in bulk, etc. Cost, including avoirdupois weights, about \$12.00.

CRUCIBLES.—Several kinds of assay crucibles are in common use, among others the Denver and the Battersea. They are made of fine clay, and may be used a number of times; the most suitable sizes are the F and G Batter-

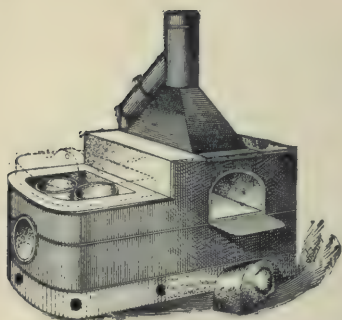
sea, and the 20, 30, and 40 gram Denver, costing from \$0.60 to \$1.20 per dozen. Covers made of clay cost about 75 cents per dozen, but for the country it is better to buy No 2 black-lead crucible covers, at 20 cents each, as they last very much longer. They can be cut to fit the crucibles.

CRUCIBLE RACK.—This is simply a small portable bench with eight or twelve holes, in which the charged crucibles may be placed in readiness for the furnace, thus avoiding the risk of upsetting, and enabling a number to be carried at once from the mixing-table. It can be made by any one who can use carpenters' tools.

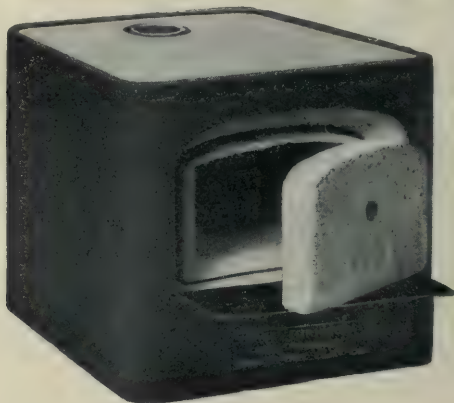


SCORIFIER.—A dish or cup formed of clay. There are different sizes, but that most used is $2\frac{1}{4}$ inches in diameter, which admits of two being placed in the width of a mint-muffle. Price, \$1.20 per hundred.

ROASTING DISHES.—Similar to scorifiers, but shallower, and from three to six inches wide; as they are used in the muffle, the size should be selected to suit. Price, \$1.00 to \$2.50 per dozen.



MUFFLE AND MUFFLE FURNACE.—The muffle is a sort of small oven, of a semi-cylindrical form, made of clay, open at the front end, closed at the back, except a narrow slit or two small holes. It is heated by being surrounded, excepting the front end, by glowing coals in the muffle furnace. In it, objects are exposed to heat out of contact with the fuel. The muffle furnace is a sheet-iron cylinder lined with fire tiles, having an opening at the back to connect with a flue or



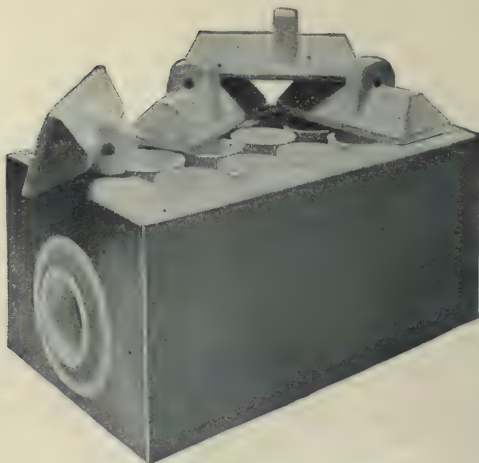
CASE MUFFLE FURNACE

stovepipe, and three openings at the front with doors, the upper one corresponding with the open end of the muffle, the middle one for introducing fuel under the muffle, the lower one for the admission of air and removal of

ashes. Immediately above the lower door is a grate. The open end of the muffle rests in the upper opening, the closed end on a projection of the lining, or, if not extending across the furnace, on a piece of fire-brick, or an assay crucible. The top of the furnace is closed by a movable iron cover. This furnace uses coke as a fuel, and is the type of furnace used very extensively a few years ago. The more modern coke furnaces are rectangular in form, and are more solidly built. They are also constructed to burn either coke or soft coal. For ordinary mine work a furnace burning either gasoline or oil is usually the best type to use. The accompanying cuts illustrate the combination type of furnace.

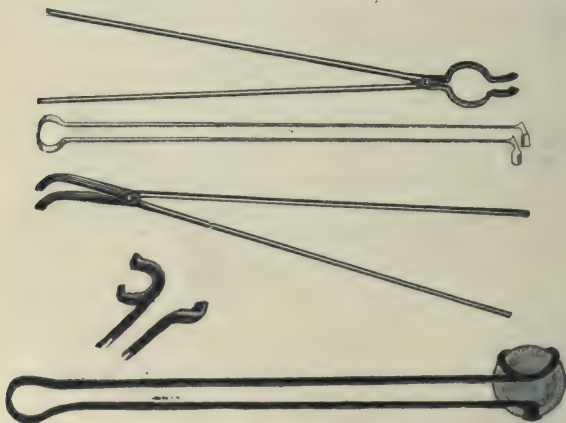
Unless the furnace is built from the floor up, it should stand on a solid table, of such a height that the operator may work conveniently in the muffle, standing or sitting as preferred. The top of the table should be protected by sheet iron, and large enough to afford room for the assay mold, cupel-tray, tongs, etc. Under the table may be a bin for fuel. When gasoline is used as fuel every precaution should be taken to avoid explosion.

MELTING FURNACE.—For fusing the assays in crucibles, also for melting bullion. The cylindrical muffle furnace, described above, may be used if the muffle be removed, and the muffle opening sealed. A standard furnace for making fusions is the one shown in the cut. Some assayers prefer to carry on all furnace operations, except the melting of bullion, in the muffle, and for this purpose use a large size muffle. Coal, coke, gasoline or oil may be used as fuel. Bullion melting is preferably done in a special furnace.



CASE CRUCIBLE FURNACE

FIRE IRONS.—Comprise a bent and a straight poker, a fire-shovel, and scorifier tongs 30 inches long; price



90 cents; cupel-tongs, 26 inches long, price 90 cents;

assay crucible tongs, 32 inches long, price, \$1.00. Other varieties of tongs are sometimes used, but are not absolutely necessary.

ASSAY MOLDS.—Made of light cast iron. Used to pour the melted assays into from crucibles or scorifiers. The conical kind with four holes is best for crucible assays, and the shallow kind with twelve round holes is the best for scorification assays. Price, \$1.00.

PLYERS, ETC.—Two pairs of flat-nosed plyers, respectively 4 and 6 inches long; prices, 35 and 50 cents, used for removing beads from cupels. A 7-inch pair of snip-shears, \$1.25. A pair of scissors, 6 to 8 inches long. A pair or two of coarse forceps, about 6 inches long, used for handling lead buttons while hammering them etc. A pair of fine steel forceps, 5 inches long, for lifting assay-weights and beads. Some use ivory-pointed forceps for the weights and weighing capsules. It is well to have a variety, but the fine steel "pincettes," rather long and requiring but very little force to close them, suit the author best for handling the smaller weights and beads, which, with stiff or coarse forceps, are apt to be lost. Prices, 50 cents to \$1.75.

SPIRIT LAMP.—Used for boiling in test-tube. Price, 50 cents. A few very small coal-oil lamps will be found convenient for various purposes, replacing, for most uses, the spirit-lamp and gas-jet.

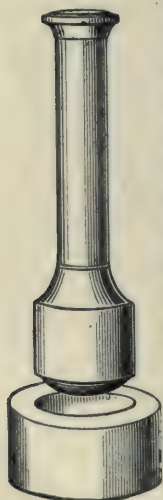
WATCH GLASSES.—To place beads and other small things on.

HAMMERS, ETC.—One steel hammer, about 6 ounces, for large beads, etc., 35 cents; another, about 1 pound, for beating lead buttons and breaking specimens, etc.: one of 4 pounds, for breaking coarse rock; a very small

one, such as is used by a watchmaker, is useful for flattening the smallest beads; a wooden mallet, a hatchet, a steel cold-chisel about 8 inches long, and another about 4 inches; a nail-brush for cleaning buttons, and a tooth-brush for beads; a camel's-hair pencil and a flat brush of the same, about two inches wide.

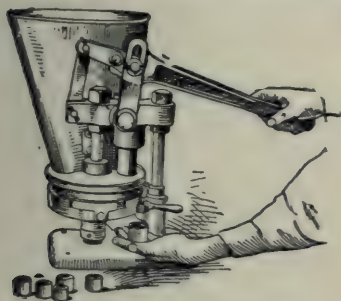
ANVILS.—One about 3 inches square, with shank by which to fix it in a block, and a flat one to lay on a table; the first to beat and clean lead buttons on, the second to use in cleaning or flattening small beads of precious metal.

CUPELS AND CUPEL MOLD.—A cupel is a small, thick cup, made of ground bone-ashes pressed in a mold. Cupels may be bought ready-made, but it is better to make them. The molds are of brass or iron, the latter being the cheaper, and equally good, if not allowed to rust. At least two sizes are required:



The larger $1\frac{1}{2}$ or 2 inches, the smaller $1\frac{1}{4}$ inches in diameter; prices, \$1.50 and \$2.20, if of iron. The cupel is used in the separation of base from precious metal, by the aid of heat, in the muffle. To make a cupel, moisten the bone-ashes sufficiently to make them cohere slightly when compressed in the hand; fill the mold, and drive the die down by a few blows with a mallet, and turn it around, to smooth the cupel. The mold, being bottomless, must be placed on something solid, as the anvil. The cupel is pushed out from the mold by means of the die; if this is very difficult to do, it is because the ashes are too dry, or the die

has been driven too forcibly; however, the best mold is one that is slightly larger at the bottom than at the top. The cupels are placed on a tray to dry. The price of bone-ashes is 6 cents per pound. Ten pounds will make about 200 medium-sized cupels.



Where many cupels are used the automatic cupel machine shown in the cut is preferable to the single hand mold, as hundreds of cupels of perfect shape, uniform in size and density may be turned out

in a short space of time.

TEST TUBES.—In nests, 3 to 6 inches; per dozen, 35 cents; single, 3, 4, 5, 6, 7, 8 inches; per dozen, 20 to 60 cents. Made of glass; used for boiling acids, etc.

TEST-TUBE RACK.—To set the tubes in; also has pins for draining tubes by inversion; price, 75 cents.



TEST-TUBE HOLDER.—Wooden tongs, with round jaws, usually lined with cork. To hold the test-tubes while hot.

DRY CUPS (Annealing-cups).—Small crucibles, very

thin; made of clay, unglazed. Used for drying and annealing the gold from an assay. Price, for best, \$1.00 per dozen.

PORCELAIN CAPSULES.—Small glazed crucibles, very thin. Used for partings, and for drying and annealing the gold from an assay. Price, for best, \$1.00 per dozen.



PARTING FLASKS.—Special form, called the Kennedy, are best. Used for partings. Price, \$1.25 per dozen.

MATRASS FLASKS.—Used for parting in the gold bullion assay. Size, 3 oz. Made of glass. Price, \$1.50 per dozen.

WATER BATH.—A dish having a cover consisting of a series of rings. By removing more or less of the rings, a suitable-sized opening is made in which to rest a vessel to be heated by boiling water. Used for drying ore, etc., at heat of boiling water.

LENS, or magnifying glass, for examining small beads of metal to see if they are clean; also for inspection of minerals.

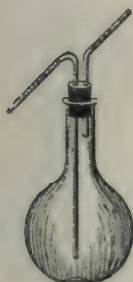
CUPEL TRAYS.—Made of cast iron, 8x8 inches, to carry cupels on; 16 holes, \$1.20.

COAL-OIL STOVE.—This is a great convenience in a country office where gas can not be had. A pan containing some sand, placed on the stove, forms a *sand-bath* for heating liquids in glass or porcelain vessels, drying samples on, etc.



GLASS FUNNELS.—Price (each): Square 2 inches, 10 cents; 3 inches, 15 cents; 4 inches, 20 cents; $5\frac{1}{2}$ inches, 30 cents.

FILTER PAPER.—Used for filtering liquids to separate solid matter. Cut in circular form, folded twice across, and applied as a lining to a funnel, into which the liquid is then poured. The clippings of the paper are excellent for cleaning glassware; 4 inches, 18 cents; 6 inches, 25 cents; 8 inches, 30 cents; 10 inches, 40 cents. Swedish is the best; cheap gray answers for filtering rain-water for assaying, and for some other purposes.

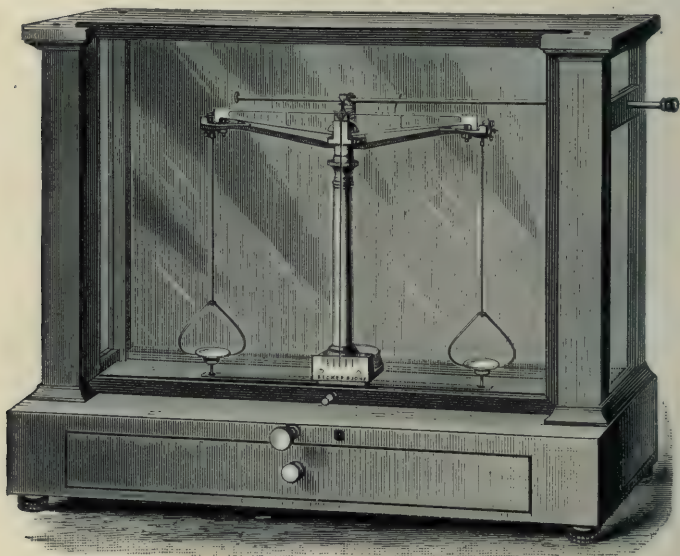


FILTER STAND.—Also used in heating a vessel over a lamp. Price, with 2 rings, 60 cents; 3 rings, 75 cents; 4 rings, \$1.00.

WASHING BOTTLE.—Used in washing objects in vessels or on filters. The bottle is to be nearly filled with water. On blowing into one of the tubes, a jet is expelled from the other. Price, 50 cents.

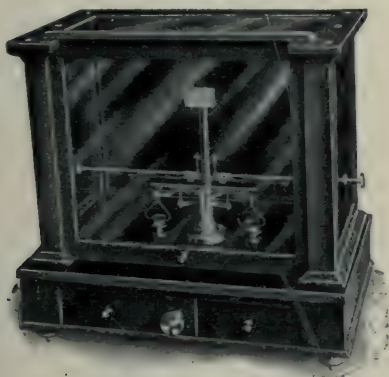
ASSAY BALANCE.—This is the most costly and delicate apparatus used by the assayer. The upper cut represents a good balance, costing \$95.00; the lower cut, an extremely delicate balance, suitable for umpire and other fine work, costing \$250.00. It is by no means advisable to buy the cheapest grades, unless in case of absolute necessity, and, if possible, one of the finer balances should be obtained for assay offices where a check with smelter or other assayer is required. A fair

balance can be had for \$65.00, but much below this price they can have no apparatus for riders, which is usually considered a defect where rapid work is essential. But in first using any balance, it is far safer to weigh by the methods of deflections, as explained later. A good balance should take at least one gram in each



pan, and should be sensitive to 1-100th milligram. It should be provided with a set of platinum weights from one-tenth milligram to one gram, and a beam-rider for weighing fractions of a milligram. It is enclosed in a glazed case, the front of which is arranged to open by an upward sliding panel, counterpoised like a window-

sash, by means of cords and weights. The case is supported by legs which are adjustable in length by screwing into brass sockets. Within the case are two spirit-



levels at a right angle the one to the other. The beam is poised on knife-edges of agate, resting on agate plates. The pans are suspended by means of stirrups with agate plates, resting on knife-edges or points fixed to the beam. A slender finger of steel descends or rises from the center of the beam, indicating its slightest movement upon a graduated arc of ivory. The distance from the center of the beam to the points on which the pans are suspended is divided into a certain number of equal parts, marked on the front of the beam. These divisions are subdivided by shorter marks. A brass bar extends across the case behind the beam; it supports a sliding rod which extends to the outside of the case, and terminates in a milled head. The sliding rod is called a *carrier*, and is furnished at its inner end with an arm extending at a right

angle to the rod, over the beam. On the arm hangs a small bifurcate weight, formed of fine wire in such a manner that it can be placed astride upon the beam, like a man on horseback. By means of the carrier, operated from without the case, the rider is placed upon the beam at any desired point, or removed at pleasure. The rider acts upon the principle of the pea of a steel-yard, and is used to complete the weighing of an object on the balance, without the necessity of opening the case.

In order that the instrument may not be injured by the weight of the beam and pans resting constantly on the delicate points of suspension, nor by any shock occasioned by the placing or removal of weights or other objects during the operation of weighing, an apparatus is provided by which, on turning a key or milled head, the beam is lifted off its bearings, and two small tables rise under the pans and receive their weight; the stems of these tables are screws, working in brass sockets, by which the height of the table is adjusted by turning it around.

Above or below the center of the beam, working on a screw-thread on the index, or on a separate slender stem, is a little ball or "cheese" of brass, called a gravity-bob; by screwing this upward or downward, the center of gravity of the beam is raised or lowered, and its sensitiveness increased or diminished. Around this stem is twined a slender bit of wire, with one end projecting in front; by turning this projecting end a little to one side or the other, the beam may be balanced.

The balance should be supported firmly, preferably on strong posts running into the ground and not touch-

ing the floors. The idea of this is to avoid the vibrations of the building, which interfere with accurate weighing. This is sometimes accomplished by placing the balance on a shelf attached to a brick wall or chimney. The legs of the scales should rest on pieces of plate-glass, to prevent sinking. In a moist climate, an open vessel containing some strong sulphuric acid or quicklime should remain constantly within the case. In a very hot and dry climate, makers recommend keeping a shallow dish containing water on the table under the balance. The acid or lime is to prevent rusting, by absorbing the moisture of the air. The dish of water is to prevent warping of the woodwork by too great dryness. A light cover of canvas, paper, or wood, in the form of a box, should be placed over the case when the balance is not in use, in order to exclude dust. The balance should not be in the same room in which ore is pulverized, or acid boiled, nor in which is any furnace. The weights used with this balance are either grains or grams, corresponding with those used in weighing the ore for the assay. If grains, the set is from ten grains to one-hundredth grain; if grams, from one gram to one milligram. In either case, the smallest is one-thousandth of the largest, and is considered as the unit, or one, of the system. (Where riders are not used, the set includes smaller weights, but these are regarded as fractions of the unit.) The weight of the rider must agree with the other weights, and with the number of divisions on the beam; in some cases it weighs ten units of the set, and the beam has ten principal divisions on one or on each of the arms, and fifty subdivisions; in others the beam has twelve divisions, and the rider

weighs twelve units; in either case, the rider, if placed on the mark 1, will counterbalance one unit of the set on the opposite pan, and accordingly for the other marks. On a subdivision it is equal to a corresponding fraction in addition to the preceding whole number. Some beams, however, are divided and numbered in twenty parts, and the rider weighs two units; its value on 1 is then one-tenth of a unit; on 2, two-tenths, etc.

The weight of a bead or piece of precious metal obtained by an assay is usually "reported" in units of the set, not in grains or grams; thus a bead weighing 1.156 grains is reported as 115.6; one weighing 0.0765 grams is reported as 76.5. One gram, or ten grains, is therefore called 1,000. In gold bullion assaying the set is generally one-half gram equals 1,000, consequently one-half milligram is the unit, and the rider weighs ten of these units for a scale with 100 divisions, or two units for a beam with 20 divisions.

The balance is adjusted and tested as follows: The case is accurately leveled, first in one direction, as from left to right, and then in the other, as from front to back, by means of the spirit-levels and the adjustable legs. The beam is then placed, not resting on the knife-edge, but on the extra supports which are thrown up for the purpose. The pans are then suspended from the ends of the beam. On each stirrup will be found a mark; near the corresponding end of the beam a similar mark. The marks on the stirrups are placed toward the front, and each stirrup is hung on its proper end of the beam. The tables under the pans are adjusted so as to take the weight of the pans without lifting the stirrups off the beam. The supports are then lowered, and the index

observed; it should swing slowly and steadily from side to side, and, on coming to rest should point exactly to zero, or the center of the ivory arc. If the index swings unequally, and stops finally on one side of the zero, the little wire which projects in front of the center of the beam must be carefully moved, and the trial repeated, and so on until perfect equilibrium is attained. The small capsules or dishes which accompany the balance are then placed, one on each pan; they must balance each other exactly, or else equilibrium must again be produced by means of the wire, and each capsule be thenceforward used invariably on the same side.

It may be here remarked, once for all, that nothing must be placed on the pans, nor in the capsules, while they are on the pans, nor must the beam or pans be touched in any way until the extra supports are raised; neither must the capsules or the weights be touched by the fingers. If it is necessary to clean the capsules, a fine soft handkerchief should be used. Dust is removed from the beam and other parts by means of a camel's-hair pencil. The weights and capsules are moved by means of forceps. Occasionally the balance may be dismantled, and the parts cleaned by rubbing with a piece of soft chamois leather, and, if necessary, a very little fine coal-oil.

The balance having been so far adjusted, must be tested. The weight 1 of the set should cause the index or pointer to swing to or near ten divisions from zero, and one-tenth, obtained by the riders, should cause a deviation of one division. The deviations should be the same on either side with the same excess of weight, otherwise the balance is badly made. The sensitiveness

can be increased to the required degree by screwing the gravity-bob upward, but if the bob is raised too high, the beam will fall on either side, and so remain, and no weighing can be done. Some scales are not provided with a gravity-bob, being adjusted once for all by the maker. In raising the supports, advantage should be taken, whenever possible, of the moment when the swing brings the pointer to zero, when they may be raised quickly; if this can not be done, the supports must be raised very gently. In releasing the beam, the support should be lowered at first very slightly, until it is seen that the beam is near enough to equilibrium to swing both ways, then promptly to the full extent; but if the load on one side preponderates so much as that the beam will evidently fall on that side too far to swing freely, the lowering of the support must not be continued, but, on the contrary, it must be raised again, and a nearer approach to equilibrium established. These cares are necessary to prevent shocks which would injure the delicate bearings.

The next point is to ascertain if the two arms of the beam are of equal length. This is done by placing counterpoising loads on the pans, and changing the loads from one pan to the other; if the exchange of loads produces no disturbance of the equilibrium, that is, if an object weighs the same on either end of the beam, the arms are of equal length. In first-class balances there is not much likelihood of a defect in this respect, the rectification of which is a work of such delicacy that a person who is not familiar with such work should not attempt it.

It must be understood that the condition of equilib-

rium, and equality in the length of the arms are distinct; either may exist without the other. The beam must be balanced by some means before any weighing is undertaken; if it is then found that the arms are of unequal length, by testing as above, recourse must be had to *double weighing*, in order to obtain the true weight of an object. The best method of double weighing, called the method *by substitution*, is to place the 1,000 weight on one pan of the balance, and counterpoise it by a special weight made for the purpose, of any suitable material, as gold or platinum; the weight is then removed, the object to be weighed is put in its place, and smaller weights added until the counterpoise is balanced; the difference between the 1,000 weight and the sum of the weights required to restore the equilibrium is the weight of the object.

It may be here observed that if, as in assaying, only relative weights are required, the inequality in length of the arms is of no consequence, provided that all the weighings of the assay are made *on the same pan of the same balance*, because then they are all affected in the same ratio, and the relative proportions remain correct. This is easily done in bullion assays, and may be so in ore assays, if a chemical balance is used which is at once large and strong enough to weigh the ore, and delicate enough to weigh the gold and silver obtained; but where, as in general, the ore for an assay is weighed on one balance and the precious metal on another, double weighing becomes necessary, if the arms of either are unequal.

Another method of double weighing is by *reversal*. The object is weighed first on one pan and then on the other, and the sum of the apparent weights divided by

two is taken as the true weight; this is not strictly correct. The true weight is the square root of the product of the apparent weights, but if their difference is small, the error is inappreciable. When it is required to weigh off a certain quantity of a substance on such a balance, the weight corresponding to that quantity is placed on one of the pans and counterpoised by any means; the weight is then removed, and replaced by the substance; the quantity of the latter required to restore equilibrium is equal to the weight which it replaces.

A careful assayer will also test the weights in order to ascertain if they agree among themselves. It is not important that they be absolutely standard but only that they are correctly proportioned the one to the other, for an assay is simply a question of the *proportionate* weight of precious metal, as compared with the weight of ore from which it is extracted, hence the weights used in weighing the ore for the assay must accord with those used for weighing the metal obtained, and all must agree among themselves according to their marks. If 1,000 parts by weight of ore, no matter what kind of weights is used, contain one such part by weight of silver, it is clear that 1,000 pounds of similar ore contain one pound of silver. The proportion once ascertained, it is easy to deduce the absolute quantity of metal in a ton of ore. The 1,000 assay weight should equal the 400, 300, 200 and 100 assay weights together; the 400 should equal the 300 and 100, and so on down to the smallest. The ore weights must be checked in a similar manner on the pulp scales, working from one of the smaller of them, after that has been found to agree with the similar assay weight. In case the ore weights are not a complete set,

the assay weights may be combined, and a quantity of granulated lead may be weighed on the assay balance as many times as may be necessary to make a quantity equal to the ore weight as marked, and placed on one pan of the pulp scales; the ore weight being placed on the other pan, it will be seen whether the two agree or not. The riders may also be tested by weighing them against the ten assay weight, if the beam has ten main divisions, or against the ten and two, if it has twelve divisions, etc., and the divisions on the beam by placing the rider on each mark in succession, and the corresponding weight on the opposite pan.*

*The implements, apparatus, etc., illustrated herein can be bought from F. W. Braun & Co., San Francisco and Los Angeles, Cal.

MATERIALS.

LITHARGE (*lead oxide*, PbO).—Twelve to fifteen cents per pound; composed of lead and oxygen; a flux, an oxidizer, a desulphurizer, and a source of lead.

A flux, because it causes refractory substances to melt at a comparatively moderate heat. It fluxes most rocks, earths, and metal oxides, hence is very destructive to the crucible if used in excess, for which reason other substances are used instead, to a certain extent.

An oxidizer, because it gives up oxygen to combustible or oxidizable substances, causing them to burn, or become oxidized; it thus burns sulphurets in an assay. It is a common error to suppose that the substances thus burned are necessarily burned *out*. On the contrary, while some are burned out, others remain in the assay, but their condition is changed; they are converted into the respective products of their combustion.

A desulphurizer, because it burns the sulphur of sulphurets, as well as oxidizing their metals, except lead and noble metals.

A source of lead, because when it gives up its oxygen, the lead remains in metallic state.

To prove these things, melt some litharge in a crucible, and throw in about one-fiftieth as much iron sulphurets in powder. A piece of lead will be gotten from a portion of the litharge; the rest fluxes the iron oxide made by burning the iron sulphuret. Or, instead of

iron sulphuret, throw in some galena; the sulphur of the galena will be burned, and lead will remain.

SODA (*sodium bi-carbonate*, NaHCO_3).—Six cents per pound; a flux, an oxidizer, and a desulphurizer.

Fluxes quartz, quartzose rocks, and some metal oxides. Oxidizes some metals. Desulphurizes galena and some other sulphurets, especially if charcoal or flour is added; the sodium combines with the sulphur. Mix some powdered quartz with thrice its weight of soda, and heat to bright redness in a crucible; the result will be a glass which can be poured out. Melt some soda with iron filings, and dissolve in water; the iron will be found to be oxidized. Melt some galena with several times its weight of soda; lead will be got.

BORAX (*sodium baborate*, $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$).—Ten cents per pound; a flux.

Fluxes clay, lime, magnesia, slate, etc., and metal oxides generally; also quartz, but not so well as soda. Melt some, and add a little powdered ore containing sulphurets; the gangue (rock, etc.) will be dissolved; the sulphurets will be found at the bottom.

Borax swells when heated, giving off water; this is sometimes inconvenient in an assay. To prepare it for use, heat it gently in an iron pan until it swells no more, then cool and grind it; it should not be melted, as that makes it hard to grind; it should be kept in a close vessel if in a moist climate. Sometimes it is used undried in lumps. Borax may be bought already ground, and is commonly used in this condition, not being dried.

CARBONATE OF POTASSIUM (K_2CO_3).—This acts the

same as sodium carbonate, with which it is frequently mixed. It is valuable in fusing lead ores.

BORAX GLASS.—Forty cents per pound; a flux, same as borax, but does not swell. To prepare it, melt some borax, cast it in thin plates, and grind to powder. One part by weight is equal to two of undried borax.

GLASS (common bottle or window).—A flux. Acts similarly to borax, but is less easily melted. Used in assays containing much lime, clay, etc.; not with quartzose ores. Also useful in assays made with much niter or litharge, to protect the pot. A quartzose ore fluxed with soda makes glass, which then fluxes the metal oxides, lime, etc., in the ore. Sometimes used in pieces, but is better ground. Heating to redness and quenching in water facilitates grinding.

NITER (*potassium nitrate*, KNO_3).—Fifteen cents per pound. First a powerful oxidizer, then a flux; also a desulphurizer. When heated gives off a large quantity of oxygen, leaving potash, which is a flux of much the same nature as soda. Niter is a desulphurizer in two ways: First, by giving off oxygen to burn sulphur; second, by the potassium combining with sulphur, as the sodium of soda does; but if enough niter be used, all the sulphur is burned, being converted into sulphuric anhydride. Niter can oxidize all metals except gold and some of the platinum group. Used to counteract the effect of too great a quantity of sulphurets in an assay, which it does by burning a part of them, which would otherwise produce too much lead from the litharge.

SULPHUR.—Six cents per pound. A sulphurizer. Used in a certain class of assay in certain cases to pre-

vent copper from entering the lead button, which it does by converting the copper into a sulphuret.

IRON (nails or wire, Fe).—A desulphurizer for galena and for compounds of silver with sulphur, but not for other metal sulphurets, as copper, zinc, etc.* Used in a certain class of assays to free lead and precious metals from sulphur. Can also combine with arsenic, keeping that out of the lead. Iron reduces litharge to lead, itself being burned, but it is not used for that purpose. Melt some borax, add some galena and a large nail; lead will be got.

SALT (*sodium chloride*, NaCl).—Used because it becomes very fluid, floats on the assay, and serves as a cover to exclude air and furnace-gases; also to wash the side of the pot; it must be dried and ground. If mixed with the assay, it tends to prevent overflowing by becoming fluid at a comparatively low temperature, thus facilitating the escape of gases.

SHEET LEAD.—Twenty-five cents per pound. Tea lead will answer. Must contain no gold.

GRANULATED LEAD (Pb).—Fifteen cents per pound. Used in the assay by scorification, in which the litharge required as a flux is produced from lead, instead of lead being produced from litharge, as in the crucible assay.

FLOUR.—Used in the crucible to produce lead from

*Iron can take all the sulphur from lead or silver compounds, setting those metals free. It only takes a part of the sulphur from pyrites, sulphuret of copper, and some other sulphurets, leaving the metals still combined with a part in the form of matte.

litharge. One part by weight of flour generally produces fifteen parts of lead, but this varies a little, according to the quality of the flour and of the litharge. Powdered charcoal is also used for this purpose; one part of charcoal produces about thirty parts of lead. Any substance which produces lead from litharge is a reducer.

ARGOL ($\text{KHC}_4\text{H}_4\text{O}_6$).—Commercial bitartrate of potash. This acts as a reducing agent, and also as a basic flux. One part of argol produces about 9 grams of lead.

TEST SILVER.—Two dollars and fifty cents per ounce, 1,000 fine. Used in the gold assay. Must contain no gold.

ACIDS.—Nitric, HNO_3 , forty cents per pound in seven-pound lots; hydrochloric, HCl (muriatic), and sulphuric, H_2SO_4 , acids. The first only is strictly necessary; it must contain no chlorine. The others are convenient for certain tests.

DISTILLED WATER, H_2O .—Filtered rain-water will answer; common spring-water is often used; it must contain no chlorine. Used in the gold assay for washing the gold.

For the sake of brevity, only the more important properties of the foregoing substances have been mentioned.

The water and nitric acid may be tested for chlorine thus: Dissolve a few grains of silver by boiling in rather dilute nitric acid, add a drop or two of the solution to the suspected water or acid in a clear glass vessel, and observe if it produces a white cloud or a milkiness; if it does so in the water, that will better be rejected, but not so the acid. Stir the acid with a glass rod, or, if in a bottle, which is best, shake the bottle well, then let it

stand until the acid is clear, and add another drop of silver solution, and so on until no further milkiness is produced; then, after settling, pour the clear acid off into another bottle for use. The water may be treated in the same way in case of need. In a mill, good condensed water can be got from the boiler (not from the exhaust of the engine).

The assays of litharge and lead for gold and silver will be found in their appropriate places. Litharge and lead always contain some silver, and this is allowed for in the assays of ore; if they contain gold also, they are unfit for use.

Any silver that is nearly pure will answer for test silver, if it contains no gold; to test it, dissolve about one-half gram in nitric acid; it should leave no residue.

All the fluxes should be ground to powder. The prices given are those at present prevailing and are liable to change; a discount is always allowed on considerable purchases.

THE ASSAY OFFICE.

THE office should properly consist of three adjoining rooms: One in which the pulverizing, fire work, and other rough and dirty work is done; another in which to weigh and mix the assay, boil the acid in separating gold from silver, and keep the fluxes, acids, crucibles, spare muffles, etc.; and a third in which to keep the assay-balance, books, and papers; but it often happens that only one room can be had, and all that can be done is to make the best of it. The muffle-furnace should be so placed that when the operator works in the muffle the light comes from behind him. The sun should not shine into the room. There should be a strong bench or table on which to use the pulverizing implements, and it is better if it rest on the ground, and not on the floor, so that the entire office may not be shaken by the blows of the pestle or hammer. A block, similar to that used by a butcher, will answer well instead of a table. Another table on which to place the pulp-scales and mix the assays will be required. Above this table, or in any convenient situation, should be shelves for packages of material, and upon the table, which should be of a good size, a long box, divided across into five or six compartments, about six inches square and deep, and lowest in front, with a hinged cover, to contain the several fluxes, etc.,* also the test-tubes in their rack, the spirit-lamp, smaller anvil, etc.

*In a damp climate it is better to keep the fluxes in separate covered vessels of tinware or glass.

The assay-scales should be so placed that the light from a window may strike them obliquely over the left shoulder of the operator while seated at his work; it is still better to have light from two sources obliquely behind the operator, in order that no shadows may be cast on the balance, either by the person or by the case-frame.†

The sun should not be allowed to shine on the balance at any time. The table on which the balance stands should be reserved for that purpose only; there should be another on which to work with pen and paper.

†If there is any difficulty in getting light from the proper direction, a mirror may be so placed as to reflect on the balance. A hand-mirror is sometimes useful to throw light on the beam while reading the indications of the rider.

PREPARATION OF THE ORE.

ALL ore assays must be finely powdered, but not the whole of a large sample need be so. Ordinarily, samples as received by the assayer may weigh from 1 to 50 pounds. A sample, if not already crushed, is broken by hammer and block, pestle and mortar, etc., and, according to its weight, should be made to pass a 2 or 4, or finer mesh sieve, and is then thoroughly mixed on a smooth cloth or table. The sample is then spread in a layer and divided, by the back of a saw blade, a trowel, or spatula, into quarters; two opposite quarters are rejected and swept cleanly off the table; the other two are again mixed, after further pulverizing, if needful, and again divided. When the sample has been quartered to about 10 pounds, it should pass the 4 mesh sieve, and when quartered to 2 to 3 pounds should pass the 30 mesh sieve; when quartered to about $1\frac{1}{2}$ pounds it should pass the 60 mesh sieve; an assay sample of about $\frac{1}{2}$ a pound is then taken out by the use of riffles or by quartering, and is made to pass an 80 or 100 mesh sieve. The sample always should be thoroughly mixed before quartering and before the charge is weighed out for assay. A sheet of strong paper or oil-cloth is suitable to mix on, by lifting an edge and drawing it forward, not simply causing the ore to slide from place to place, but so as to roll the sample upon itself, and finally to heap it in the middle, then again spreading by the spatula, and so several times, after which it is again quartered.

Dried mill pulp and tailings samples are best prepared for assay by passing them through a 20 mesh sieve, thus breaking up all clots; about $\frac{1}{2}$ pound is then taken out by the use of riffles or by quartering, and is ground to pass a 60 or 80 mesh sieve. The 20, 60 or 80 mesh sieves used should be kept specially for this work, because of the danger of introducing coarse gold into the tailings sample.

The assayer should remember that the amount of work to put on any sample depends upon the time allowed and the facilities for crushing, grinding, etc., also upon the sample itself, whether values are supposed to be distributed uniformly or not, and the care with which it was originally taken.

For mixing a sample after it has reached a certain fineness, no implement is equal to the finger. Heap the ore, then with the finger beginning at the center of the heap, trace a spiral to the edge and back to the center. Again heap by lifting the edges of the sheet, and again spread by the finger, and so on.

Without perfect mixture at each stage of division, the final sample will not be a true one, and this final sample must again be well mixed, in order that each assay taken from it may also be a true sample of the whole. An idea of what is required may be got by adding a little flour to a finely powdered sample of dark-colored ore, or charcoal to a light-colored one, and mixing until the tint is uniform, without streaks or spots.

Each time that a sample is ground and sifted, the whole of it must pass the sieve, unless there are particles of tough matter, such as metal, or silver glance, etc., which can not be ground to a powder; in this case

the tough matter must be kept, and no further division of the sample can be made, as it must all be weighed and treated as directed further on.

Damp ore must be dried. In particular cases all samples, whether they appear damp or not, should be dried *after* being powdered, then allowed to cool before weighing the assay. Many substances, such as clay, for instance, lose more and more water at successive degrees of heat up to whiteness, wherefore there must be a standard temperature for the drying. That standard is the heat of boiling water; hence the sample is dried on the water-bath.

All implements used in powdering and sifting must be cleaned, lest the sample be contaminated by some remains of a former one. In many cases, simply wiping the mortar, etc., with a cloth will suffice, but after rich ore, the tools must be cleaned by grinding some barren quartz, sand or glass. Sieves are cleaned by brushing and tapping.

The prepared sample is put in a sample-pan with a tag, on which is marked the number of the sample, and any other desired particulars, such as the character of the ore, as a guide in dressing, or the metal for which it is to be assayed, etc.

The character of the ore can, in general, be ascertained sufficiently, and most conveniently, by an examination of it in the lump, before grinding. When this can not be done, as in the case of samples which come already ground, recourse must be had to washing (panning) a little of the powder in a dish, by which the character and proportion of sulphurets may be judged, if there are any. The color and general appearance

also furnish indications, or special tests may be applied, some of which are given further on.

Note—A sample which consists entirely of sandy or granular matter, as concentrates, for example, is difficult to mix, because of the tendency of the smaller and denser particles to sift between the coarser and less dense, and accumulate at the bottom. Such a sample may be slightly moistened, mixed, and quartered as many times as may be required, or it may be ground before mixing and quartering, so as to destroy its sandy character, and the lesser sample thus get dried, and, if necessary, ground, etc. On the other hand, a sample consisting largely of impalpable powder or floury matter is also difficult to mix, because of a tendency to clotting. Such material can not be mixed by simply heaping and spreading, but should be passed, little by little, several times under the spatula, or through a sieve, so as to rub and mash the clots. A fair proportion of fine powder and grit is best for the mixing. In powdering ore, take but little at one time; work by alternate or combined pounding and rubbing, and sift often, tapping the sieve while also shaking it, to prevent the meshes becoming clogged by particles of ore. It is best to weigh out the assay immediately after mixing the sample, as the heavier and richer particles will gradually settle toward the bottom of the mass of powder, especially if that is exposed to vibrations from the pounding of other samples in the vicinity, or from people walking on the floor. Hence, if a sample stands long before the assay is weighed out, it should be mixed before the weighing is done. This is particularly important in the case of samples which are rich in gold.

WEIGHING THE CHARGE.

SIT or stand squarely in front of the scales, and see that they balance with the capsules on them. In special "pulp scales" the pans themselves seem intended to be used as capsules, being unattached and furnished with handles; nevertheless, I prefer to weigh ore or fluxes in a small porcelain dish counterpoised by a piece of lead.

Put the weights on the left-hand pan.

After a little practise, it will not be necessary to weigh the fluxes, etc., except in some cases, niter and flour; in general, these things can all be measured closely enough.

The fluxes should be measured or weighed first, then the pulp weighed and placed on top for the mixing.

The assay-ton system of weights is so much more sensible and convenient than either ounces or grams that I have resolved to adopt it generally where I have occasion to give definite quantities. Where only proportions are required, the term *parts* will be employed. The sign for the assay-ton is A. T. (See article on "Calculating the Assay.")

MIXING AND CHARGING.

THE crucible assay may be mixed on a sheet of writing-paper (glazed paper is better), and poured from that into the pot, care being taken to leave nothing behind. A more usual way is to put first the fluxes, or some of them, and then the ore, directly from the weighing-capsule into the pot as it stands in the rack, or on a sheet of paper; the mixing is then done with the handle of a teaspoon. The really best way is to mix by means of a pestle and mortar. The pots must not be more than two-thirds full, 'on account of the swelling of the charge when heated. An assay should not be pressed or packed down in the pot, for, if this be done, some substance is liable to be blown out by the sudden and forcible escape of gas; it may, however, be tapped or shaken down with advantage. Pots which have been used for rich ores should not be employed for poor ones; and for important assays, whether rich or poor, new ones should be taken. This applies also to scorifiers. The scorification assay is mixed in the scorifier. To prepare a scorification assay, first pour one-half the requisite amount of granulated lead into the scorifier, add the ore and mix with the spatula, then pour the remaining half of the lead over the mixed charge, and finally add the borax glass.

ASSAY OF LITHARGE.

THE litharge frequently contains an appreciable quantity of silver, and it is desirable that it should do so, as otherwise the bead from a very poor ore, which may, nevertheless, contain some gold, might sink into the cupel so as to escape observation. Each lot, as opened for use, must therefore be sampled and assayed; the ore assays made with it must be corrected by the result. Where, as in a mill, the same quantity of litharge is constantly used in the assays, the readiest way of making the correction is to assay that quantity, and place the resulting bead on the weight-pan when weighing the beads; but where varying quantities of litharge are used, it is better to treat a larger quantity, note the weight of silver got, and correct each ore assay according to the litharge used in making it.

Place in a crucible this mixture:—

Litharge	4	A.	T.
Flour	$\frac{1}{10}$	"	"
Soda	1	"	"

Cover with salt, and melt quickly; when cooled, clean and cupel the button. Make two such assays, and part one of the beads for gold, which, however, should not be present. (See articles on "Melting in Crucibles," "Cupellation," and "Parting.")

We must also determine beforehand the oxidizing power of niter and the reducing power of charcoal and argol. This necessity arises because of impurities in the reagents. By oxidizing power is meant the amount of

metallic lead that one gram of niter will oxidize, and by reducing power, the amount of metallic lead that one gram of reagent will reduce from litharge.

To determine the oxidizing power of niter, mix the following charge, fuse in clay crucible, and weigh resulting button:—

Niter	3 grams
Charcoal	1 gram
Litharge	60 grams
Soda bicarb	30 grams

In the absence of niter, we would have obtained a button of certain weight, say, 27 grams, due to the charcoal present. The button obtained will weigh, say, 12 grams, that is, 3 grams of niter have oxidized $27 - 12 = 15$ grams of lead, whence 1 gram of niter will oxidize 5 grams of lead.

To determine the reducing power, make up charges:—

Argol.	Charcoal.
Argol 1 gram	Charcoal 1 gram
Litharge 30 grams	Litharge 60 grams
Soda 15 grams	Soda 30 grams
Salt cover....	Salt cover....

The weight of the buttons will tell how much lead is reduced by 1 gram of charcoal or argol. The reducing power follows.

SYSTEMS OF THE CRUCIBLE ASSAY.

IN all fire-assays of gold and silver ores, the precious metals are collected by means of lead, from which they are afterwards separated. In crucible-assays the lead is produced from litharge by the action of reducers. The crucible-assay is divided into two systems, either of which may be applied to any ore, but is best adapted to certain cases.

In the assay by the second system, or "nail-assay," litharge is used than is requisite for the production of lead; the excess assists in fluxing the slag. All base metals, except the required lead, are oxidized and dissolved in the slag. This assay is quickly made, and generally gives accurate results; it requires some modification for the various ores, as to the fluxes proper and the reducers or oxidizers by which the production of lead is controlled; sometimes a preliminary assay is necessary.

In the assay by the second system, or "nil-assay," litharge is not used as a flux for the gangue, but simply as a source of lead, and only so much of it as may be necessary for that purpose is added in the dressing. Base metals, except lead and perhaps antimony, remain in the form of oxidized or sulphureted slag, or of speiss, that is, combined with oxygen, sulphur, or arsenic, as the case may be. Antimony sometimes passes more or less into the lead, and, as it interferes with cupellation by causing the cupel to crack, ores containing much antimony must not be assayed on this system. Arsenic combines with nickel,

cobalt, copper, or iron, forming a button which is usually hard and brittle, and which separates readily from the true, or lead button. If the ore contains copper, that will be reduced, and will contaminate the button, unless sulphur or arsenic be present to combine with it. By keeping such a charge containing copper and zinc basic, that is by adding but little silica, a softer button will be obtained.

The method requires a higher heat and longer time than the other; it can not always be depended upon for a true result as to the silver; the gold is got with more certainty. This system is convenient for the determination of gold in auriferous pyrites, also in cases where litharge and crucibles are expensive, and where great accuracy is not requisite as to the silver, or where the ore is of low grade, so that error is not of great importance.

With some ores, especially those rich in lead and not so in copper, the second system gives as good results as any; yet, on the whole, it must be conceded to be an inferior process as to silver. It is sometimes convenient to make a small assay by the first system for the silver especially, and a much larger one by the second for the more accurate determination of the gold in an ore.

The following reactions will give an idea of the chemistry of the two processes, and will indicate what should be added to the charge to get certain desired results:—

PRELIMINARY ASSAY.

IN the crucible-assay by the first system, ores which contain a great proportion of sulphurets would reduce too much lead from the litharge; others containing less would reduce the right quantity; others, again, too little or none, and an ore containing a large proportion of the higher oxides of lead, copper, iron, manganese, or chromium would prevent the reduction of lead by a reducer unless the latter were present in sufficient quantity to counteract their oxidizing effect and leave a surplus for reduction. An excess of reducing power in the ore may be counteracted by means of niter.*

There are two limits to the size of the button; it must be large enough, enough litharge having been reduced through the mass to collect all the precious metal, and at the same time there should not be a useless excess of the lead, which would occasion loss of silver in the subsequent cupellation. Fifteen to twenty grams is the best size for from one-third to four A. T. of ore, and is the best size for cupelling.

An experienced workman can generally judge what to do, for, although the weight of lead got ought not to be much less than ninety per cent of that of the ore used, yet there is a considerable margin for variation on the other side. The writer rarely makes a preliminary, but in

*I have used manganese dioxide instead of niter with good results. An assay so made may require an extra dose of borax or glass if the gangue is basic, as lime, etc.

doubtful cases dresses the assay according to his judgment, with more or less of the various fluxes according to the nature of the gangue, and with an addition of niter or an extra dose of flour, as the case may be; this is, however, difficult when the ore consists of a mixture of oxidizer and reducer, as copper glance and iron red oxide, etc. In case a preliminary is required, it may be made as follows: Consider whether the ore is likely to be a reducer (that is, it contains a considerable proportion of sulphurets), or an oxidizer (that is, carries much red oxide of iron, black oxide of manganese, black oxide or blue or green carbonate of copper, red lead or a chromate). If it is a reducer, take one-tenth A. T. of ore and 5 A. T. of litharge; mix in a crucible, cover with salt, and melt with care, that no coal falls in; the weight of the resulting button above 0.1 A. T. multiplied by 2.5 is the weight of niter required in an assay of 1 A. T. of the ore; for a half-ton assay take half that quantity, etc.

If the button weighs much less than 0.1 A. T., the deficit multiplied by ten times the fraction of an A. T., representing the quantity of flour which would bring down 1 A. T. of lead from the litharge, is the weight of flour to be used in an assay of 1 A. T. of the ore.

The proportion of lead which the flour will bring down depends on the quality of the flour and the purity of the litharge; it varies from 12 to 16 times the weight of the flour, and may be readily found by melting 3 A. T. of the litharge, mixed with some soda and 0.1 A. T. of the flour, under a salt cover, then, after cooling, weighing the resulting button.

If the ore brings down no lead, it is not a reducer; if it brings down from 90 to 100 per cent of its own weight,

it may be dressed for the assay proper without either niter or flour.

If the ore is supposed to be an oxidizer, melt one-tenth A. T. of it with about 2 A. T. of litharge, some borax, and so much flour as, according to the above described experiment, should bring down a certain quantity of lead. Now, if you get that quantity, the ore is not an oxidizer; if you get less, it is, and the deficit is the measure of its oxidizing power; then the difference between the weight of lead got and that which should have been got if no ore had been present multiplied by ten times the number of A. T. of flour which was found to be necessary to bring down 1 A. T. of lead from the litharge, is the weight of *extra* flour to be used in an assay of 1 A. T. of the ore; half as much for one-half A. T., etc. Suppose it had been found that 0.08 A. T. of flour would bring down 1 A. T. of lead, and we take 0.1 A. T. of ore and 0.02 A. T. of flour with 2 A. T. of litharge, etc.; suppose we get 0.11 A. T. of lead, that is, 0.14 A. T. less than the quantity called for by the flour; then 0.14, multiplied by 0.8, gives 0.112 A. T. of *extra* flour required for 1 A. T. of the ore. Or, we might weigh a full assay, a ton or half ton, of the ore, and dress it regularly as hereafter directed, adding so much extra flour as we judge to be required; then, if a suitable button be got, it may be cupelled for the precious metal; otherwise, another assay may be made with the required correction.

If fractional A. T. weights are not at hand, the work can be done in grams; but the A. T. weights can easily be made of lead or other metal, down to 0.01 or lower, or the parts of the ton may be reduced to grams in the form of

a table to be kept at hand. The main point is to remember that 1 part of niter is equal to the oxidation of from $3\frac{1}{2}$ to 4 parts of lead, according to its purity, or an equivalent of sulphurets, and 1 part of flour reduces from 12 to 16 parts of lead from litharge, or, which is the same thing, from 0.06 to 0.08 ton of flour brings down 1 ton of lead, the exact proportion to be found by experiment.

DRESSING THE CRUCIBLE ASSAYS.

FIRST SYSTEM.

FROM what has been said of the properties of the different fluxes, it will be seen that the proportions in which they are used may be varied to suit the character of the ore. Mitchell gives one general formula for all ores of gold and silver, as follows:—

Ore	1 part
Litharge	5 “
Soda	1 “
Borax glass.....	1 “

Salt to cover,* another part of borax over that, and reducer (flour) or oxidizer (niter), if needed, in accordance with the indications given by a preliminary.

This formula is of extensive applicability, admitting the variation in respect of flour or niter, and it is well to keep the proportions in mind; but the same objections apply in a less degree to this as to the exclusive use of litharge as a flux, with flour or niter to suit. These objections are the expense for litharge, which is comparatively costly, and the rapid destruction of crucibles, which

*Some assayers omit the salt, thinking that it only serves for washing the sides of the pot, and may be dispensed with for economy's sake. It is certainly not indispensable, but it assists greatly in preventing an overflow, by its easy fusibility imparting a quasi-liquid condition to the assay at an early stage, thus facilitating the escape of expanding gas, especially if mixed instead of being put on the top.

is an important item in districts remote from a city, and where, as in mills, a great many assays must be made daily. In a majority of cases, 3 parts of litharge suffice; in many 2 are enough, and in some $1\frac{1}{2}$, but, when the litharge is thus spared, it may be necessary to alter the proportions of the other fluxes, which the student will be enabled to do by a careful study of their action. It should be remembered that soda is a flux for quartz; borax for earths and metal oxides generally, as is also the glass formed by soda with quartz; litharge for all.

As to making a preliminary every time, it is out of the question. The workman must, in many cases, rely on his judgment, or have recourse to the second system, or "nail-assay." For ordinary ores, containing little or no sulphuret, some quartz, clay, lime, iron oxide, etc., this formula will in general suffice:—

Ore	1	part	} Fuse quickly, keep in furnace 5 to 10 minutes after subsidence.
Litharge	2	"	
Soda	1	"	
*Dried borax ...	$\frac{1}{2}$	"	
Flour	1-12	"	
Salt to cover.			

and 1 part borax on top.

If the ore is nearly all quartz, the borax may be reduced and the soda increased; or, as much soda may cause the assay to boil up too much, the litharge may be increased instead. On the other hand, if earthy matter or metal oxide predominate, the soda may be reduced

*Or rather less of dry soda ash, and borax glass.

one-half or more, and the borax increased even to doubling, or, in place of so much borax, some glass may be added, in which case it may be better to retain all the soda.

If the button got is too large, it may be scorified to a suitable size, but if the assay is very important, it will be better to make another with less flour in the ratio indicated by experiment. (See article on "Preliminary Assay.") If the button is too small, repeat with more flour in the same ratio to the deficit. Thus the assay answers all the purposes of a preliminary, while, if the result is satisfactory, time is saved.*

If the ore contains sulphurets, less flour must be used or none may be needed; or, again, niter may be employed.

If silver only is to be determined, or, rather, precious metal, not parted, and a delicate balance is accessible, a quarter A. T., or even a smaller quantity of the ore, may be used, and, being melted with a plenty of litharge, according to the nature of the ore, the button may not be too large for immediate cupellation; this is an excellent method for argentiferous galena, silver glance, and such sulphureted ores generally as do not throw down an inordinate proportion of lead.

*This will not answer with an ore containing a large proportion of sulphurets other than galena or silver glance, because the proportion of litharge used will not suffice for the complete decomposition of the sulphurets. A preliminary is then proper.

The proportion of some sulphurets which will bring down a suitable quantity of lead are:—

	For silver.	For gold.
Iron pyrites	11 per cent	12½ per cent
Copper pyrites	12 “	13½ “
Zinc-blende	13 “	16½ “
Sulphuret of antimony . . .	16 “	13 “
Gray copper	15 “	“
Galena	34 “	“
Sulphuret of copper	23 “	25 “
Sulphuret of manganese . .	13 “	13½ “

Any excess may be met by means of niter.

It is important that the slag should be thoroughly oxidized, retaining no vestige of a sulphuret. The different kinds of sulphurets require different proportions of litharge to effect complete oxidation, as follows—only a small part of the litharge is reduced to lead. :—

1	gram	of	charcoal	will	reduce	about	30	grams	of	lead.
1	“	“	flour	“	“	“	15	“	“	“
1	“	“	argol	“	“	“	7	“	“	“
1	“	“	Fe pyrites	will	reduce	about	10	gr.,	require	50
1	“	“	Cu	“	“	“	7	“	“	30
1	“	“	Zn sulphide	“	“	“	6	“	“	25
1	“	“	Sb	“	“	“	7	“	“	25
1	“	“	Pb	“	“	“	3	“	“	5

The following table will also prove useful:—

% of pyrite	amount of ore	lead reduced.
2	1 A. T.	5 grams.
5	“	12 “
10	“	25 “
15	½ A. T	19 “
20	“	25 “
30	“	37 “
40	“	50 “
50	“	63 “
70	“	88 “
100	“	125 “

The excess of lead reduced by ores of the type studied is oxidized by niter, 1 gram of niter oxidizing 4 grams of lead, or we may express its oxidizing power in terms of the reducing-agent, as follows:—

2 ½	grams	of	KNO ₃	will	oxidize	1	gram	of	pyrite.
1 ½	"	"	"	"	"	1	"	"	stibnite.
2/3	"	"	"	"	"	1	"	"	galena.
¼	"	"	"	"	"	1	"	"	lead.

Some workmen use nails with these ores in this system of assay. No doubt the iron will prevent the formation of any lead matte, but as iron is a reducer, it is liable to throw down too much lead; it also reduces copper if present.

The simultaneous use of niter and flour or charcoal in certain assays is a relic of ancient practise, based on somewhat misty theories of reaction at different temperatures, and is retained by some who might be expected to know better, but who seem to occasionally prefer the rule of thumb to the rule of reason. The student may rest assured that, in an assay for gold and silver, when flour is needed niter is not.

Some, even chemists, put niter into an oxidized coppery ore, with the insane idea of "burning out the copper." Every chemist ought to know that, in the first place, the copper is never burned *out*, but remains in the slag; and, secondly, that it must be slagged in the form of *red sub-oxide*, not as a *green glass*. The black oxide or the carbonate is an oxidizer in an assay, and, so far from requiring niter, calls for an extra quantity of reducer to bring it to the required condition. The red oxide of copper in an ore is already in the proper condition, and for finely divided metallic copper such as can pass the assay-sieve,

litharge in liberal quantity is the safe and appropriate oxidizer, which will convert it into the red oxide with no danger of forming a green slag.

That a coppery button is sometimes got from an assay by this system is due to the fact that lead can reduce the copper oxide to metal, unless a sufficient quantity of litharge is present, when the copper remains in the slag as red oxide; hence, if the button is much contaminated by copper, the need of more litharge in the assay is indicated.*

One way in which to get rid of all difficulty as to the proportion of niter is to use so much as to completely oxidize every constituent of the ore, decomposing any excess by heat, and throwing down a button by means of charcoal.

A neat way in which to make the assay of gold and silver ores containing much copper is to treat the weighed assay with hot nitric acid until the copper is dissolved; filter and wash. To the filtrate and washings add hydrochloric acid or a dilute solution of common salt as long as a precipitate is produced. Collect the precipitate on a separate filter, and wash it. The whole of the silver will be on the filters, that portion which existed in the ore as chloride, iodide, or bromide on the first, the remainder on the second, also converted into chloride. It will not answer to add salt or hydrochloric acid during the treatment of the ore, because the proper quantity can not be known, and an excess would cause gold to be dissolved and lost, if present.

Dry the two filters with their contents; dress the residue

*Basic charge.

from the ore with litharge, borax, and soda as a crucible assay by the first system, proportioning the fluxes to the quantity of substance. If there should be much separated sulphur, some niter may be needed. Put the whole into a crucible. Dress the other filter with a small quantity of litharge and soda, and put it also in the pot. In adjusting the flour or niter, it must be remembered that the filters will act as reducers, unless they have been burned to ashes in the drying, which may be done on a roasting-dish in the muffle very speedily. Cover with salt, and on that put some borax. Melt and proceed as usual. Assays made in this way work very cleanly and quickly, as there is not much besides quartz and silver chloride to melt. The chief advantage is that a large quantity of ore can be taken, it being greatly reduced by the acid treatment.

In using niter to counteract the excess of reducing-matter, it may happen that, although the niter has been adjusted in accordance with the indications of a preliminary, little or no lead is got.

The natural supposition then is that too much niter has been used; this is an error. On repeating the assay with a smaller proportion of niter, the result is no better than before, while, if it be made with a slightly larger proportion, the apparently paradoxical result is that more lead is got, though not the full quantity called for originally; this has puzzled many assayers, and is understood by very few; it has led some to the practise of using nails in a nitered assay, at the risk of getting too much lead, and of forming oxysulphides in the slag, which is stated on good authority to be dangerous. It is true that I have suggested the use of a small quantity of niter in the assay of such ore by the second system, but the litharge used

in that is not in excess of the quantity of lead required, and too much lead can not be got, while the little niter intended to be used, if any, is only enough to burn a portion of the *excess* of sulphur which exists in iron pyrites beyond what is required to retain the iron in the form of a sulphide containing the minimum proportion of sulphur, to which condition it must be reduced in order to insure the extraction of the precious metal.

The difficulty spoken of is caused, not by an excess of niter, but by a deficiency of litharge. It has already been stated that iron pyrites require 50 parts of litharge to effect complete oxidation, reducing only 8 or 11 parts of lead, that is, very much less than the entire quantity of lead in the litharge; the reason of this is that when litharge is combined with a certain proportion of iron oxide it loses the power of oxidizing sulphurets. When the ore consists almost entirely of iron pyrites, which in this class of assay must be completely oxidized, a large quantity of iron oxide is formed; this engages a corresponding quantity of the litharge, rendering that powerless to decompose sulphurets of any kind, even galena. Now suppose we use niter enough to oxidize about 90 per cent of the pyrites, the remaining 10 per cent (the ore being practically all pyrites) requires 50 times as much litharge, that is, 5 times the weight of the entire assay. Besides this, a quantity of litharge is required to combine with the iron oxide produced by the action of the niter on 90 per cent of the pyrites, otherwise the 10 per cent of pyrites can not be oxidized, because the litharge intended to act on them is otherwise employed. The result is that little or no lead is got, since little or no litharge is reduced; it remains in the slag, partly combined with iron oxide and

partly with a portion of the sulphur of the 10 per cent of the pyrites.

It can now be seen why more niter may cause more lead to be reduced by leaving less than 10 per cent of the pyrites to be acted on by the litharge, for although more iron oxide is produced, it does not consume litharge in the same proportion as is required by the pyrites; the remaining quantity of the latter is then completely oxidized, and an equivalent quantity of lead is thrown down. If a sufficient quantity of litharge had been used, instead of more niter, the 10 per cent or so of pyrites would have been oxidized, and the calculated quantity of lead got. The indications of a well-made preliminary may always be relied on if enough litharge is used in the assay proper.

From the foregoing it appears that the assay of this class of ore by the first system, using a graduated quantity of niter, must require more than the 5 parts of litharge prescribed for all ores by Mitchell.

For well-concentrated pyrites, the following dressing is suitable:—

Ore	1	part
Niter	1.7	"
Litharge	8-10	"
Soda	1-2	"
Borax	1	"
Glass	$\frac{1}{2}$ -1	"

and salt to cover.

The litharge may be lessened as the proportion of soda and glass is increased.

When, on pouring an assay fluxed according to the first system, it is found that, although the slag is sufficiently liquid (or otherwise) the lead is scattered, beads of it

clinging to the walls of the crucible, it indicates either that the assay has not been sufficiently heated, or that not enough borax, silica, or litharge has been employed. The assay may be at once returned to the crucible from the mold, provided that no part of the slag has been lost by overflowing, and remelted with the necessary correction; it can then be cleanly poured.

An ore which contains a very large proportion of iron oxide, and not any, or very little, sulphuret, works better with only about $1\frac{1}{2}$ part of litharge, but an addition of glass is requisite. I prefer glass to the precipitated silica recommended by some, because an excess is less liable to make a pasty slag, the glass itself being fusible.

SECOND SYSTEM.

The following is a general formula for assays by the second system:—

Ore	1	part,	} . Melt and leave in strong fire about 20 minutes after fusion.
Litharge	$1\frac{1}{2}$	"	
Soda	3	"	
Borax	$\frac{1}{2}$	"	
Flour	1-10	"	
Iron.	1 to 3	nails	
Salt to cover.			

The purpose of the nails is to free the lead from sulphur and arsenic. Twelvepenny nails are suitable; if too long, cut them; thick wire is equally good.

When the ore contains a great quantity of pyrites, a little niter may be used; it assists by removing a part of the excess of sulphur which pyrites contain; the flour should then be omitted. If the button is too small (sup-

posing the assay to have contained the proper quantity of litharge or lead in some form), or if it contains silver or arsenic, the nails have been removed too soon (see article on "Melting"), or too little soda has been used; if it is coppery, not enough sulphur has been present, and in such case, that is, when the ore is more or less oxidized and at the same time contains copper, a little sulphur may be added in the dressing, but the silver will not all be obtained; it may fall short by as much as ten per cent, and the more sodium sulphide is formed the less silver is got, so that if sulphur is added, it should be no more than is requisite to keep copper out of the button.

In no case should there be any distinct matte above the button, but all the metal sulphides should be blended in a black slag.

EXAMPLES OF DRESSING.

THE borax was only air dried.

Eureka Mine, Arizona.

Ore	10	grams	}	The flour was varied according as the ore contained more or less oxidizing matter.
Litharge	20	"		
Soda	7	"		
Borax	15	"		
Salt to cover.				

This ore consisted of oxide and carbonate of iron, black oxide of manganese, carbonate of lime, clay, silica, and a sprinkling of molybdate of lead and horn silver. The assay fused very quietly, and gave excellent buttons and a glassy slag.

Silver King Mine, Arizona.

Ore	10	grams
Litharge	40	"
Soda	7	"
Borax	5	"
Flour	$\frac{3}{4}$	"
Salt to cover.		

The ore contained quartz, calcite, porphyry, blende, galena, a little pyrites, heavy spar, and much native silver.

Material from the concentrators:—

Tailings.....100 grams

Litharge125 “

Soda125 “

Borax 10 “

Flour 1 “

Salt to cover.

Concentrations10 grams

Litharge50 “

Soda10 “

Borax10 “

Niter 1 “

Scorification worked well with 8 parts lead and some borax glass.

The same ore by the second system:—

Ore.....20 grams

Litharge .20 “

Soda40 “

Borax10 “

Flour 2 “

Nails 3 “

Kept in furnace 20
minutes after subsi-
dence.

Concentrations10 grams

Litharge20 “

Soda30 “

Borax 5 “

Flour.

Nails 3 “

The ores of the Blind Spring District, consisting of partzite, mixed with quartz, oxide of iron, and manganese, gave good results with three or four parts of litharge, flour, and *either* soda or borax, or both. With soda,

and not borax, the slag was as liquid as could be desired, but when cold was granular. With borax the slag was glassy. The results were equal. At San Andres, in Honduras, being desirous of economizing both the pots and the litharge, and the ore being nearly pure quartz, with a little clay and iron oxide, I used the following dressing:—

Ore	1	part
Litharge	2	"
Soda	1	"
Borax glass	1	"
Charcoal	1-30	"

A salt cover was dispensed with. Later, having to economize still more, I further reduced the borax and litharge while slightly increasing the soda; the slag then contained scarcely any lead, being simply a glass of soda and quartz with some borax and the iron oxide of the ore, through which, when cold, the button was plainly visible; this was a gold ore. Some check assays made with plenty of litharge gave no better results. At Curaren, also in Honduras, the ore was mainly of silver, the gangue quartz, with a very small proportion of iron pyrites. In this case I got along very well with:—

Ore	1	part
Litharge	1	"
Soda	2	"
Borax	a	trifle

and flour enough to reduce all of the litharge, so that the slag contained no lead. For the oxidation of the very small portion of sulphurets present I trusted to the action of the soda, the litharge being reduced by the flour. The slag was a perfectly clear glass.

THE MELTING IN CRUCIBLES.

THE furnace should have a damper. The fuel should be in pieces not larger than an egg, nor much smaller than a walnut, that is, for the general purpose of melting in crucibles. The finer portion can be used advantageously when working the muffle, as less draft is then required, and by placing fine fuel on the top of the fire the muffle is more evenly heated in all parts. The fine fuel is also useful when the fire burns unequally, as by it the draft can be checked in any particular part. When the muffle-furnace is used for the crucibles also, it is sometimes desirable to use a rather short muffle, not extending entirely across the furnace, the rear end being supported by a piece of fire-brick or an old crucible; this allows of crucibles being placed at the rear, as well as along the sides of the muffle. If the muffle is removed in order to save it and give more room for crucibles, it should not be replaced without first removing a portion of the glowing coals and placing a bed of cold fuel on the remainder; the removed hot coals can be put above the muffle, together with fresh fuel; in this way a fracture of the muffle by intense and sudden heat is prevented. When the muffle is removed for the melting, the opening in the front part of the furnace which it occupied may be closed by a plug of fire-clay, which may be conveniently made by cutting off about two inches of the closed end of an old muffle; this is easily done by means of a coarse file. When

many meltings are to be made, it is always better to have the muffle out.

To place the crucible in the fire, make a nest for it among the glowing coals, seize it with the bent tongs in one hand, place and sustain it, while, with the cupel-tongs in the other hand, the coals are packed around it. If the fuel is charcoal, a cover must be used to prevent bits of the coal falling in, but with coke this is not always necessary, instead a glowing coal may be laid across the top of the crucible.

Place the pots in one unvarying order, so that any given one may always occupy the same place according to its number; thus it will not be necessary to mark them, though this may also be done by means of redden.

If more assays are to be made than the furnace can contain at once, a second set should be prepared before the first is melted; then, as soon as number one is ready to pour, remove it carefully from the fire, preserving the nest which it occupied, pour it, and in its place put the first of the new set, which will be number 7, if the furnace holds 6 pots, and so on with the others.

If time is an object, it is a good plan, while weighing and fluxing the assays, to let an assistant place in the fire a full set of old crucibles as dummies, to be removed one by one and replaced by charged pots when ready. If any of the assays fail, note the numbers, and make them again after all the others are done; for certainty, celerity, and convenience, system is indispensable.

The assays will swell when heated, hence it is proper to partly or wholly uncover the pots when fusion begins, and to watch that they do not boil over, which is more likely to occur if they are closely covered; this precau-

tion may become needless when, by practise, the exact manner of fluxing a given ore so as to avoid the danger is known.

The tendency to boil over proceeds from several causes, as the use of too much soda, or of undried borax, the latter especially, with slow heating, so that if undried borax is used, the assays may be put at once into a strong heat; but this can not be done when much niter is employed, as that causes foaming. The boiling up of an assay may be checked by throwing in a teaspoonful of salt. It sometimes happens that an assay is heated too much at the bottom before the upper part is hot, producing fusion below, while a crust remains above, and is pushed out of the pot by the expanding gases; to guard against this, place the pot well down near the grate, and pack hot coals closely about the upper part.

If the slightest overflow occurs, or if the fusing mass comes in contact with the cover, the assay must be rejected. If the slag appears thick, try the addition of a little borax; if that does not help it, soda will. In adding soda, look out for boiling up. A certain proportion of soda may sometimes make a thick slag, when less would work well; borax, glass, or litharge is the remedy.

When the fusion is finished, in from five to twenty-five minutes after subsidence, the pot is uncovered, with care, that no coal may fall into it, seized in the bent tongs, removed from the fire, the sides rinsed in the slag by a circular swinging movement, tapped on the edge of the furnace to settle the lead, and the still liquid contents poured into the mold. The pot is completely inverted and tapped against the mold. The overflowing of the slag in the mold is of no consequence. The pot should be

examined; it should retain only a glaze of slag, and if any pasty lumps or globules of lead remain in it, the assay is defective.

If nails have been used in the assay, they must be removed before the pouring. With tongs seize a nail, wash it in the slag and tap it against the pot, then examine it; if it is free from adhering lead, reject it, and take another the same way; if lead is seen to stick to the nail so that it can not be washed off, it shows that the assay is not finished, either for want of *heat* or of time, and it must be returned to the furnace.

When cooled, the assay is turned out of the mold and the slag examined; it should contain no globules of lead; the button is then beaten to a cube, brushed, marked, if so desired, and placed in readiness for cupellation.

The buttons must be soft and malleable, and separate easily from the slag when cooled. The color of the slag varies with the constituents of the ore and the proportions of the fluxes. The slag is not always glassy, nor is this important, but it must be liquid, not pasty, when poured.

Pots which have not been cleanly poured may be rendered fit for re-use by melting in them the usual fluxes, litharge, etc., without ore, then pouring.

SCORIFICATION.

IN this method the litharge required for fluxing is made from lead during the operation. Scorification is well adapted to rich ore, but not to that which is poor, on account of the smallness of the quantity treated or the time and fuel consumed; however, ores containing nickel or tin are perhaps better scorified. Buttons containing tin or nickel can not well be cupelled until scorified. Ores are scorified with an addition of granulated lead and, generally, borax.

Granulated lead, like litharge, contains silver, and must be assayed. Take—

Granulated lead, 2 or 4 A. T.

Powdered glass, a little.

Mix in a scorifier. Place in the heated muffle, and close the door until the lead is melted, then open the door and maintain a moderate red heat, keeping the lead fused. When the lead is covered by the slag, remove from the muffle and pour into the assay-mold. Return the scorifier to the muffle, and as soon as the assay is cool enough to separate the slag, return the lead to the scorifier, and so on until the lead is of a suitable size for the cupel; weigh the resulting bead, and note its weight and that of the lead used in the assay-book.

Borax, quartz, or glass are used as fluxes, the quantity varying with the character of the ore, earthy or basic ores requiring much more than the acid ores. Too much borax causes too much slag at first, and is consequently

often introduced later in the operation. This excess of slag prevents the complete decomposition of the sulphurets, and silver remains with the oxy-sulphurets in the slag.

Ordinary ores require from 8 to 12 parts of lead; galena, or silver glance, 2 parts. Those containing much iron, zinc, or tin, or of which the gangue is lime, require more lead, sometimes as much as 32 parts to one of ore. Nickel and cobalt may require repeated scorifications with fresh additions of lead up to 100 parts before a soft button is got. A small quantity of borax is beneficial, unless the gangue is quartz. With an unfamiliar ore, it is best to make several assays, each with a different quantity of lead; if that one in which the greatest quantity of lead was used gives the highest result, another should be made with yet more lead, and so on until two assays agree. The following is a general formula for ordinary ores:—

Ore.....	0.2	A. T.
Lead.....	2.5	“

and a little dried borax, unless the gangue is quartzose.*

Mix one-half of the lead with the ore in the scorifier; cover with the remaining lead, and sprinkle on the borax. Place in the red-hot muffle. Close the door until the lead is thoroughly melted. Open the door, and moderate the heat. The ore will be seen floating upon the lead; it soon takes the form of a ring, leaving the lead exposed; this is called the “bull’s eye.” If the bull’s eye does not appear, the assay will fail, unless, perhaps, with an oxi-

*When the ore contains much sulphur, a part of the lead may be replaced by litharge.

dized ore; this is sometimes caused by the ore not being finely ground. When the bull's eye appears, maintain a cupelling heat by managing the damper and the door of the ash-pit. When the bull's eye is covered by the melted slag, add a couple of lumps of borax by means of the cupel tongs; close the door and give a higher heat for about 5 minutes. When the slag is perfectly fluid, the assay may be poured; the scorifier should be returned to the muffle (unless it is much corroded, when a new one must be taken), because the button may be too large, and must then be rescorified. The button is cleaned and prepared for cupellation as in the crucible-assay. The slag must contain no prills of lead.

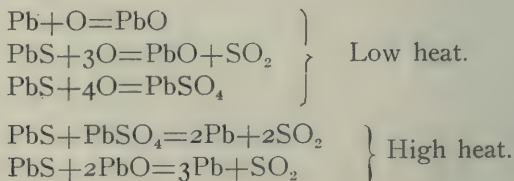
When very sulphurous ores are assayed, it is best to omit the borax until the bull's eye is closed. The scorifiers are handled by means of the scorifier-tongs, and may be used until too much corroded, though the same rules apply to these as to crucibles in regard to re-use. As a scorifier may occasionally be pierced by the litharge formed, it is well to have an extra bottom in the muffle; such a bottom may be bought, or made by cutting another muffle. The muffle bottom, extra or not, should be protected by a thin layer of bone-ashes, which will absorb the spillings in case of accident, and may be scraped out. The scorifiers may be, in a measure, protected by rubbing the inside with redde. Scorification furnishes a convenient means of purifying, as well as lessening the weight of, a button got in the crucible; by this means, also, any substance, except the noble metals, may be removed from lead.

Some teachers hold that scorification is the only reliable method for the assay of silver ores, while others

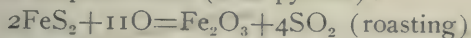
contend that it is inferior to the crucible-assay when the silver is present as chloride; others, again, maintain the opposite of this. In the case of chlorides, I usually employ a little soda in the scorifier. With equal quantities of ore, the crucible method (first system) is by far the quicker, and I am of the opinion that, if enough litharge be used, it is quite as accurate as scorification. Scorification appears to have the advantage of simplicity in its favor, and yet, if we employ an abundance of litharge in the crucible, as we must of lead in the scorifier, and omit the use of niter, the advantage almost or quite vanishes, while on the other hand, by availing ourselves of the oxidizing power of niter, in the case of sulphureted ores, we can treat a considerably larger quantity of ore, in proportion to the weight of lead to be cupelled (or re-scorified) by the crucible method than by scorification. At all events where gold is to be determined the crucible is preferable. In the scorification of the calcareous ores, the escaping carbon dioxide gas sometimes causes a serious loss of substance by projection.

The following reactions express briefly the chemistry involved in the different processes of scorification of different ores:—

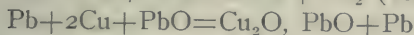
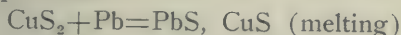
Galena ores:



For sulphide ores (iron pyrites):—

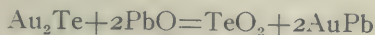


Copper ores:—



Similarly for arsenic and antimony ores.

Tellurides:—



If the PbO be placed on top of the charge, it reacts with the Au_2Te fumes and retains the gold.

A TABLE OF SCORIFICATION CHARGES

Ore	A. T.	Lead in grams	Borax Glass, Etc.
Average Ores	$\frac{1}{5}$	45	$\frac{1}{4}$ Gram
Cu Sulphides	$\frac{1}{10}$	75-90	$\frac{1}{2}$ "
Cu Matte	$\frac{1}{10}$	90-100	$\frac{1}{4}$ SiO_2 + $\frac{1}{2}$ Borax
Fahl Ores	$\frac{1}{10}$	60-75	$\frac{1}{2}$ Borax
Pyrite	$\frac{1}{10}$	45	$\frac{1}{4}$ "
Fe_2O_3	$\frac{1}{5}$	50	$\frac{3}{2}$ SiO_2 + $\frac{1}{2}$ Borax
Galena	$\frac{1}{2}$	45	$\frac{1}{4}$ Borax + Fe Nail
Zinc Blende	$\frac{1}{5}$	100	$\frac{1}{2}$ Borax + a little C
Arsenic	$\frac{1}{5}$	100	$1\frac{1}{2}$ Borax Glass
Tellurides	$\frac{1}{10}$	50	10 gms. PbO on top + $\frac{1}{4}$ Borax
Rich Au & Ag Ores	$\frac{1}{10}$	45	$\frac{1}{2}$ Borax Glass

CUPELLATION.

By this process lead is separated from precious metal. The cupel should be somewhat heavier than the button;* it is placed in the brightly red-hot muffle by means of the cupel-tongs, and the door is closed. When the cupel is thoroughly heated, the button is placed upon it.† Again the door of the muffle is closed, until the lead is well melted, when it is opened to admit air. The lead now appears luminous. The heat and the draft through the muffle must be regulated by means of the damper and the ash-pit door, so that the lead smoke rises to about the middle of the muffle. The button gradually becomes smaller, and colored spots are seen moving upon its surface; these spots are litharge which sinks into the cupel. The heat should now be reduced; not so much that the button shall seem to swim in litharge, but so that a crop of small crystals of litharge shall be formed on the cupel. After a time the button appears covered by rainbow-colored rings, which seem to move rapidly; it becomes a "bead" which seems to rotate upon its axis; at this instant the cupel is pushed further back, where the heat is

*A cupel will absorb about twice its weight of litharge, but if it is saturated, the bead may not be quite clean, and the litharge may injure the muffle.

†The cupel-tongs are used here; they may be steadied, if necessary, by contact with the edge of the muffle. I always place a few small pieces of charcoal in the front end of the muffle, in order to equalize the heat.

greater, or a glowing coal is placed close to it. Suddenly the bead becomes still, and in a few seconds more the cupellation is finished. The finishing is called the *brightening* or *blick*.

If the bead consists largely of gold, which is known by its greenish color while fused, or if it is not larger than the head of a large pin, the cupel may now be removed from the muffle; not so with the larger bead, consisting principally of silver. Melted silver absorbs oxygen from the air, and expels it while cooling; if a large bead is cooled suddenly on the surface, while the cupel is still highly heated, the gas, when expelled from the interior, breaks forcibly through the solidified crust, carrying with it some molten silver, a part of which is liable to be lost. Such an accident may be prevented by causing the bead to solidify very slowly, or from below upward; this is done in either of two ways: First, by inverting over the bead on the cupel another cupel heated to redness; second, and more surely, by drawing the cupel toward the front of the muffle, watching it, tongs in hand, and at the instant when the bead ceases from trembling on the cupel being lightly tapped on one side by the tongs, pushing the cupel back to the hotter part of the muffle. The surface of the bead is thus prevented from solidifying, or is again melted, while the partially cooled cupel, absorbing the heat, causes the solidification to proceed from below, the gas escaping quietly. The disruption of the bead as described is called sprouting or vegetation. At the instant of solidification, the bead suddenly emits a flash of light.

The signs of a successful cupellation are as follows: Some crystals of litharge are seen on the cupel; the bead

is well rounded, bright on the upper surface, unless when slightly frosted by incipient sprouting, or by being kept too long in a fused state after the blick, crystalline below, adhering slightly to the cupel. A bead which does not adhere a little to the cupel contains lead; too strong adherence indicates that the button contained other base metal and not enough lead for its complete removal; the bead then probably contains copper. In either of these cases the bead must be enveloped in a small piece of sheet lead and recupelled. As several cupellations may be conducted at once, the cupels may be marked by vertical scratches on the sides, in order to avoid mistakes.*

*The writer never marks the cupels, but places them on the tray and in the muffle in one unvarying order, according to their numbers. When many assays are made at once it is best to work so that those in front shall be finished first, in order that the finishing may be managed, and the cupels removed easily from the muffle at the proper time, for if left in long after the brightening a large loss of silver may result. If the buttons are all of one size there can be no objection to charging them all on to the cupels as soon as the latter are hot enough; otherwise, small buttons which may from their numbers fall to the rearward cupels, should be reserved until the larger ones nearer to the front have made some progress.

If for any reason the cupels are placed out of the regular order of position in the muffle, a chart on a piece of paper should be made showing the situation of each number.

In important assays of rich ore or bullion only so many cupels should be worked at one time as can be moved back or forward, etc., at will.

Finally, in poor and comparatively unimportant assays, extreme particularity is neither requisite nor feasible. The main point is to guard against excessive heat. Practise makes perfect, and rules are for tyros; so take some test silver, and lead, and work away on cupellation, noting the losses, until you find out what you can do.

Each *set* of assays is numbered 1, 2, 3, etc., irrespective of the numbers of the samples or deposits from which they are made, which, however, must not be lost sight of. On removal from the muffle, the cupels are placed on the cupel-tray and carried to the small anvil. The larger beads are seized by the flat-nosed plyers, laid on the anvil, again grasped well within the jaws of the plyers, and forcibly compressed; this loosens any adhering litharge or bone-ash, which is then removed by brushing. Very small beads are removed by the pincettes, laid upon the anvil, turned on the side, and flattened by a blow from the small hammer, which has the same effect as the compression in the plyers. Extremely small beads may be rolled on the anvil under the face of the hammer; these should be examined by the aid of the lens, to see that they are clean, and, if necessary, rubbed between paper. Each cleaned bead is placed on a watch-glass bearing the set number of the assay on a disk of paper pasted to the convex side, so that it can be read through the glass. The glasses are ranged on a tray similar to the cupel-tray.†

Some assayers replace the cleaned beads on the cupels, and thus carry them to the assay-balance; it is a questionable practise, and leads to the occasional loss of a bead. If the cupel is placed within the scale-case, the result is dirt; if not, the bead is usually carried some distance in the forceps, and is liable to be dropped to the floor, where a very small bead can not be found. The watch-glass containing the bead is placed close to the pan

†The dry-cups may be used instead of watch-glasses and need not be numbered if placed in regular order.

of the balance, and loss of the bead is scarcely possible, or the beads are removed from the glasses and placed in a row within the scale-case, then weighed in succession.

The weight of each bead is noted in a book kept for the purpose, opposite to the set and sample numbers; under the weight is noted the correction due for silver in the litharge or lead used in the assay, which, being subtracted, leaves the net weight of precious metal obtained from the ore. In assaying an ore which is likely to contain no silver worth notice, it is proper to add a small piece of gold-free silver to the button for cupellation, in order to insure a bead of convenient size, and to prevent a possible loss of gold by its sinking into the cupel; if the added silver is first weighed, any silver which the ore may yield can be determined.

NOTE.—There is always some silver lost in cupelling, but it is not usual to make a correction except in the assay of bullion. See Part II. The loss may be approximately ascertained by recupelling the bead, before parting, with a weight of lead equal to that of the original button. The loss of weight in the second cupellation will give an idea of that in the first; but as the heat used and time occupied may be different, the loss may also differ materially in a large bead. A better way is to smelt out another button, add enough lead to the first bead to make a button of equal weight with the new one, and cupel the two side by side. They will then lose equally, as nearly as may be, and the difference of their weights added to that first got will be the truth, and will be equal to the weight of the second bead plus the loss sustained by the first in recupellation. Thus:—

Weight of first bead.....	347	
Weight of second bead.....	346	...
First bead recupelled.....	342	342
	—	—
Differences	4	5
Old bead.....	347	new 346
	—	—
True weight.....	351	351

WEIGHING THE BEAD.

WHEN about to weigh a bead, the operator must first see that the assay-balance is in equilibrium; if this is not the case, dusting by means of the camel's-hair brush, or wiping the capsules with a fine handkerchief, will frequently make it so; the extra supports may also require to be cleaned occasionally, as they sometimes adhere slightly to the beam or pans, drawing one side down when lowered. When the weight of a bead or other object is required, it is best placed on the left-hand pan, because the right hand is then conveniently employed in adjusting the weights on the right-hand pan, while the left hand operates the turnkey by which the supports are raised or lowered. (In some balances the extra supports are fixed, and the planes on which the beam rests when in action are movable; the principle is the same.)

When equilibrium is nearly attained, the case must be closed at each trial, because the slightest current of air will disturb the action of the balance; it is here that the great convenience of the riders and carriers is realized. The weights having been adjusted to the nearest 10, or lower, if so preferred, the case is closed, and the operation finished by placing the rider on the beam at that point at which it produces equilibrium. It is better that the beam should swing a little, as that proves it to be free; it may be caused to do so, when necessary, by a gentle touch of the carrier. An object should not be weighed

while it is hot, as currents of air would be produced which would make it appear too light.

It may be known when the balance is in equilibrium without waiting for the beam to come to rest, which, with a very sensitive instrument, would be tedious. The oscillations diminish continually, so that no two will be exactly alike, but if the mean of two swings to one side is sensibly equal to the intermediate swing to the other side of zero, the balance is in equilibrium. When riders are not used, the fractions of the unit may be estimated by the oscillations of the pointer; they will be of greater amplitude on one side of zero than on the other, and the middle point between any two consecutive extremes is very nearly that at which the pointer would come to rest if allowed to do so. More accurately, the middle point between the mean of two deviations on one side and the intervening deviation on the other side of zero is that at which the pointer would rest. If, for example, the pointer swings 5 divisions to the right, then 3 to the left, and again 4 to the right, the mean between 4 and 5 is $4\frac{1}{2}$, and the middle point between $4\frac{1}{2}$ to the right and 3 to the left is $\frac{3}{4}$ ths to the right; or the beam may be allowed to come to rest and the deviation noted.

The value of this amount of deviation must be found by calculation from the observed deviation caused by a known preponderance of weight. Thus if it has been found by trial that the one weight causes the pointer to stop at 5 divisions from zero, the value of 1 division is 0.2 and of $\frac{3}{4}$ ths of a division is 0.15. In any case, the swing is useful as an indication of the weight required, and the assayer should study the action of his instrument

under different loads. The bead, having been weighed, must be parted, unless the ore is known to carry no gold.

There are two methods of weighing by the oscillations, and this fact, together with the indefinite manner in which the terms designating the position and movements of the pointer are used by different writers and operators, has caused some confusion and misconception among students.

The one method is to take the *excess* of movement on either side of zero as the indication of the excess of weight; the other is to take the distance from zero at which the pointer will finally rest as such indication. The first method will give twice as many divisions of the arc as the second. Hence the value of a division is but half as much in the first as in the second.

In order to clear the subject of all ambiguity, I propose the following terms: Range, swing, and rest. Range is the total movement of the index, counted in divisions of the arc (incorrectly called vernier by some). Range may extend to each side of zero, and is then written $+$ and $-$, plus being usually the right-hand side, minus the left, as $+5-3$. Or range may extend from any division on either side of zero; as $+5-0$, or $-6+0$. Again the pointer may move to either side and not return to zero, as $+7+3$, that is, the pointer goes to $+7$ and comes back to $+3$, or $-7-3$ on the other side. Range has no value as an indication of the amount of preponderance, but it affords a means of calculating swing and rest.

Swing is the excess of movement to one side or the other of zero, caused by a preponderance of weight on one of the pans; hence a balance in equilibrium will have range, if the beam be set in motion, but can have no swing in the sense which I propose for that term. Swing is equal to range when one extreme of range is zero; it is the difference of the distances from zero when the pointer goes to each side of zero, that is, when the signs of the distances are opposite; it is the sum of the distances when the signs are similar, because if the pointer marks $+5$ and comes back to $+3$, it would mark $+8-0$, if the beam had impetus enough, or $+9-1$, etc., in each instance giving $\text{swing} = 8$.

Range is a matter of observation only. Swing may be a matter

of observation, for if impetus enough be given to the beam to make the pointer move to right and left of zero, a time must come when the gradual decrease of movement will, practically speaking, cause it to touch zero at one extreme, and when that is the case, as said above, swing is equal to (identical with) range. But swing may be calculated from observed range at any time when the beam is oscillating, as shown above.

Rest is the distance from zero at which the pointer will stop if allowed to do so. In this sense a balance in equilibrium can have no rest, though, as before remarked, it may have range. Rest is always the half of swing; it may be observed by waiting for it, or it may be known in advance by finding swing and dividing that by 2.

Swing, and therefore rest, may be deduced from a single observation of range, but more accurately from the mean of several, thus: Note on a piece of paper three (or more) extremes in one direction, and the intervening two (or more) extremes in the other direction, prefixing to each its appropriate sign; find swing by adding the means together if the signs are similar, subtracting the lesser from the greater if the signs are opposite. In the first case the sign of swing will be the same as that of range; in the second, it will be that of the greater quality. Rest takes the same sign as swing.

Range may be increased, whenever desired for convenience, by wafting with the hand a slight current of air against either of the pans, after which the case must be closed, and a few moments allowed to elapse before beginning the observation. Examples: Range (an average) is $+8-3$ as the signs are opposite, swing is the difference, $= +5$; rest is $+2\frac{1}{2}$. Again; range is $-8+3$; the signs are opposite and swing is -5 ; rest, $-2\frac{1}{2}$. Let range be $+7+2$; the signs are similar and swing is the sum $= +9$; rest is $+4\frac{1}{2}$. If range is $+6-0$, swing is $+6$, and rest is $+3$; or if range be $-6+0$, swing is -6 , rest -3 .

The value of swing or rest for the balance in use may be found by trial with a known preponderance of weight on either pan; it varies slightly with the load in the pans. Whether the preponderance of weight indicated by swing or rest must be added to or subtracted from the weights in the weight-pan must

be left to the common sense of the workman, since it depends upon which pan contains the object to be weighed. If, however, the signs are used as here suggested, and the object be on the left-hand pan, and the index of the balance points downward, the value of a + swing or rest must be added, that of — subtracted.

Weighing by the oscillations is useful when riders are not used, and when a balance is not very sensitive.

Weighing by the riders is much more rapid than by the oscillations, but it requires a more sensitive balance. The sensitiveness of a rider balance should be at least equal to 1-10 of a milligram, or preferably 4-100 of a milligram for one division of the arc.

PARTING.

SILVER is soluble in nitric acid; gold is not, hence, if we boil an alloy of gold and silver in nitric acid, the silver is dissolved, the gold remains; but in order that the separation may be complete, it is necessary that the alloy shall contain at least twice as much silver as gold, and that it be in the form of a thin sheet, unless it contains a much larger proportion of silver. With from 2 to 3 parts of silver to 1 of gold, the separation is perfect (practically speaking), and the gold remains in a single piece; with a larger proportion of silver the gold remains as a dark powder. The beads obtained from an ore assay frequently contain a very large proportion of silver, and are then at once boiled with nitric acid in a test-tube until no more red fumes are seen and the particles of gold have been collected together, when the acid is carefully poured off; the tube is then nearly filled with pure water, the gold allowed to settle, and the water poured off (usually twice). The tube is now filled with water and held between the fingers of the right hand; a dry-cup is inverted over it and retained by the thumb. By turning the wrist, the tube is inverted, the gold settles through the water to the bottom of the dry-cup, which is now right side up, the mouth of inverted tube "cabin it. When the gold has all settled, the dry-cup is held by the left hand, the tube by the right, and the latter is carefully raised, allowing air to enter and water to escape, nearly filling but not overflowing the cup. A pause, to allow

the disturbed gold to again subside, and by a dexterous movement, like breaking it off, the tube is removed from the cup, at the same time being turned mouth uppermost. The spilling of some water from the tube is of no consequence, provided it does not overflow the cup, by which gold would be lost, but a skillful operator will scarcely spill a drop. The cup now contains water and the gold; it is gently tapped and manipulated until any separated particles of gold are gathered together; the water is then poured off. In each pouring off of acid or water from the gold, a glass rod, test-tube, or dry-cup, is held to the lip of the vessel containing the gold; down this the liquid flows steadily, without danger of loss of the metal. The gold remains in the cup, is drained as much as possible, and any remaining water is absorbed by the porous dry-cup. The dry-cups, marked with redde if so preferred, and containing the gold, are placed on a tray and taken to the muffle, in which they are placed by means of the cupel-tongs (or a special pair with circular jaws), and heated to redness, again placed on the tray, and, when cool, carried to the assay-balance, and the contents of each weighed in its regular order. The gold usually adheres slightly to the dry-cup; it must be loosened by the point of the fine steel pincettes, or by means of a needle, etc., and transferred to the weighing capsule by inverting the dry-cup over that and tapping the cup.* The weight of the gold is noted under the

*It is a good plan to examine with a lens, and remove any foreign particles by touching them with the moistened point of a needle, to which they will adhere. A sail-needle with the eye end inserted into a cork, which serves as a handle, is a convenient instrument.

net weight of the appropriate bead, from which it is subtracted, leaving the net weight of the silver.

To those beads which do not contain enough silver for the parting, more must be added. The cases in which this addition must be made are as follows:—

1. If the bead is yellow, it requires the addition of 2 or $2\frac{1}{2}$ times its weight of silver, according as it is pale yellow or darker.

2. If, on attempting the parting, the bead is found to be blackened, but not much attacked, it requires the addition of 2 parts of silver.

3. If, after parting, the weight of the gold is found to be more than one-third of that of the bead, it must have as much as $2\frac{1}{2}$ times its weight of silver added, and be again parted.

This addition of silver is called *inquartation*. For this purpose some test silver, cut in small pieces, is kept on a watch-glass in the scale-case. For small beads the silver is not always weighed, but a piece is selected which is known to be sufficient. It is better weighed; the gold can then be kept in one, or, at most, two or three pieces, and there is less danger of loss in the washing.

The silver and the bead are placed in a *cornet*, or capsule, made by folding a small piece of thin sheet lead in the shape of a hollow cone, which is then closed and folded as a little pocket; this is cupelled and the bead cleaned as before, flattened on the anvil, annealed by heating to redness, parted, washed, "cupped," heated to redness, and weighed. If the gold does not fall to powder in the parting, it should be boiled a second time for several minutes in fresh acid before cupping. The flattened bead can be annealed on a piece of charcoal

before the blowpipe flame, or on a clean cupel in the muffle.

For parting a bead not larger than a pin's head, a $\frac{3}{8}$ -inch tube is suitable; for a larger bead, a larger tube should be taken. The depth of the acid in the tube should not much exceed the diameter of the tube, for safety against bumping. Heat but slightly until the action diminishes, and then boil gently. It is best to keep the tube in motion, shaking, as that tends to prevent bumping. A small quantity of gold may easily escape observation in a test-tube, unless the boiling be continued until the acid is colorless and the particles of metal gather together; by then pouring off the greater part of the acid, adding a fresh quantity, and again boiling, the gold is obtained in a more compact state, better for the washing and cupping. The mouth of the tube should be directed away from the person during the boiling. In looking for the gold, hold the tube over a white object.

Some assayers prefer to use a small glazed porcelain capsule for the parting; cupping is then unnecessary, the gold being washed and dried in the capsule. If the parted gold is scattered, a lively stirring round with glass rod will cause it to collect. As the glazed capsule does not absorb the moisture, it must not be heated strongly until the gold is dried, otherwise the boiling of the water may scatter the particles of metal, or even throw them out. Wipe the interior of the basin carefully with a small piece of filter-paper, but avoid touching the gold, then dry below boiling heat; finally heat to *low* redness. Too high heat will cause the glaze to soften. The method is convenient when many assays

are to be made, because a number can be parted at the same time on the sand-bath. However, small flat-bottomed matrasses might be used equally well on a sand-bath, or an arrangement for supporting a number of test-tubes in an oblique position, which is better than the vertical.

The use of the Kennedy flask is advisable where there is possibility of the gold breaking up. They are heated on a sand-bath or similar contrivance.

In the parting it has been found best to use acid of two strengths, first dissolving the silver in nitric acid of 1.16 specific gravity, and after washing, finishing with acid of 1.26 specific gravity. This insures that all the silver is dissolved, with less danger of breaking up the gold.

Another excellent way is to place the flattened bead in the test-tube, or other receptacle, fill to the required depth with water alone, add a drop or two of strong nitric acid, and heat gently. If action commences the bead will part; if there is no action on continued heating and the addition of another drop or two of the strong acid, pour off the solution, wash, dry, and alloy with twice its weight of silver. Flatten and proceed as before. *When action is complete*, pour off the spent acid, and add a fresh solution of strong acid, and heat to boiling. Boil for one minute, then pour off the acid, wash two or three times, dry and anneal. If the action of the first acid is too violent, dilute with water. By this method a bead may always be parted in one piece, no matter what the proportion of silver to gold.

Chemically-pure concentrated nitric acid has a specific gravity of 1.42. To save time, many assayers

use but one acid, of 1.20 specific gravity, one part of water to one of acid. In general, to determine the ratio of water to acid in making up acid of any desired specific gravity for parting, let 1.42 be the acid strength and 1.xy be the desired strength. Then, $\frac{42}{xy} - 1 = \text{vol-}$ ume of water necessary to add to one volume of acid.

CALCULATING THE ASSAY.

THE weights of gold and silver are reported as already said, in units and decimal fractions of the system of weights in use. The best system is the gram or metric system. Gold values are reported as so many dollars per ton, or as so many Troy ounces (1 Troy ounce gold worth \$20.6718) per ton. Silver values are best reported as so many Troy ounces per ton. There is likely to be some confusion if this method is not adopted for silver, because the assay value of silver is \$1.2929 per Troy ounce, being the value it had some years ago as compared with gold; at present silver is worth as a commodity, less than half that, and the value thus found must be discounted, according to the market, to get the commercial value; however, assays are still sometimes reported on the basis of \$1.2929 per Troy ounce for silver.

There are two simple methods of calculating the number of Troy ounces of each metal per ton of ore.

First—Suppose 20 grams of ore are taken for assay, and 2.42 mgs. of gold are obtained from this amount of ore; by simple calculation we have

$$\frac{2.42}{20.000} \times 100 = .0121 \text{ per cent.}$$

.0121 per cent of 29,166 (see below) = 3.53 Troy ounces of gold per ton of such ore.

Second:—The simpler and better method is to use the assay ton (written A. T.) system. It is derived as follows:

One avoirdupois pound=7000 Troy grains.

2000 pounds=1 ton.

$2000 \times 7000 = 14,000,000$ Troy grains in one avoirdupois ton.

480 Troy grams=1 Troy ounce.

$14,000,000 \div 480 = 29,166 +$ Troy ounces in 1 avoirdupois ton.

The unit of the system is the assay ton=29.166 grams, or 29,166 milligrams. Hence milligrams correspond to ounces, and there will be as many ounces of metal per ton as there are milligrams of metal per A. T.

NOTE.—In assays made for the purpose of investigation of a process, or in other important cases, especially with rich ore, it is advisable, after detaching the button, to return the slag to the pot, remelt it, throw in some litharge mixed with carbon, and, when all is well melted, pour, and cupel the button. The resulting bead is to be added to that first got for the weighing. Of course, results must be corrected for the silver contained in all of the litharge which has been employed.

The cupellation loss should also be determined and corrected for, either by the method shown on page 88, or by assaying the saturated part of the cupel, as directed on page 106, which, however, will not show the loss by volatilization.

ASSAY OF ORE CONTAINING COARSE METAL.

WHEN ore contains coarse metal which can not be passed through the sieve, the entire sample must be weighed. The coarse metal which remains on the sieve must also be weighed; its weight deducted from that of the entire sample leaves the weight of the powder. These weights must be noted; the sample then consists of 2 parts, each of which must be assayed. If the coarse metal is not in too large quantity, it may all be scorified with its weight of lead and a little borax, and the button cupelled; then, as the weight of coarse metal is to the weight of fine metal in the bead, so is the weight of an ordinary assay to the weight of fine metal which that quantity of coarse metal would give; from this the value of the coarse metal per ton is deduced. The powder having been assayed, also, we find that the whole sample contained so many grams of ore, worth so much per ton, and so many (the coarse metal), worth so much per ton; this is just the same as if we had so many tons of each quality, instead of grams, etc., and all we have to do is to find the average value per ton of such a mixture. To do this, we multiply each quantity by its value per ton, and add the results together; this gives us the total value of the two lots, which, divided by the united weights, gives the value per ton of the mixture.

Suppose the total weight of the sample to be 565 grams, consisting of 560 grams of powder, assaying

\$40 per ton, and 5 grams of coarse metal, assaying \$30,420 per ton, then—

560 tons at \$40 per ton contains	\$ 22,400 00
and 5 " 30,420 " "	152,100 00
and 565 " "	\$174,500 00

Dividing the total amount by the total number of tons, we get \$308.85 as the value of one ton of ore; this is a simple example; if the ore contained both gold and silver, it would be necessary to calculate for each, in order to get the value of the ore for each.

In the case of silver ore containing native silver or silver glance, etc., the method generally used is as follows: The entire sample, or a suitable quantity thereof, having been weighed, is finely powdered and sifted. The matter remaining on the sieve is not weighed, but is either scorified with lead or melted in a crucible with litharge, borax, and soda, adding a little flour; the resulting button is cupelled, and the value of the fine silver got is computed for the entire sample at so much per ton; the powder is also assayed in the usual manner for value per ton, and the two values are added. The quantity of ore to be taken for the sample depends on the coarseness of the grains of metal; it should be sufficient to give a good average of the lot. If the sample submitted is a piece of moderate size, the whole must be weighed and ground; in other cases, as a sample of ground ore or concentrations, a convenient quantity is 600 grams.

NOTE.—In case a few particles of silver, silver glance, etc., should refuse the sieve, if the proportion of these to the entire

sample is small, the difficulty may be overcome by dissolving the tough particles in nitric acid, adding enough hydrochloric acid to convert all of the silver to chloride, drying the whole, and grinding the dried mass in the wedgewood mortar with a little of the ore powder, then thoroughly mixing it with the rest of the sample. This method is to be recommended when such tough matter is encountered at a rather early stage in the grinding and quartering of a large sample, as it would be inconvenient to pass so much ore through the finest sieve.

Sometimes the tough matter may be made to pass by repeatedly grinding it with a little of the powder which has already passed through the sieve.

If the metal is gold, it may be dissolved in aqua regia, the liquid evaporated, and the residue ground with some of the powder and then mixed with the whole. The mixing in these cases must be done with especial care.

When a small mill is used instead of the pestle and mortar for grinding, it sometimes causes the coarse metal to pass the sieve if the gangue is quartzose.

ASSAY OF ROASTED ORE FOR SOLUBILITY.

THIS is to ascertain what percentage of the silver in roasted ore can be extracted by leaching, which is generally equal to that which can be got by amalgamation. From a true sample of the roasted ore, weigh out two assays. Leach one on a filter of coarse filter-paper with a cold solution of sodium or calcium hyposulphite* of density about 5° Beaume, until the leach gives no dark precipitate on addition of a drop of solution of a polysulphide.† Dry the assay (filter and all) on a roasting-dish in the muffle, raising the heat so as to burn the filter.

Dress and melt the leached and the unleached sample. Cupel; part the beads, and calculate the percentage of the silver extracted from the leached sample.

To make a polysulphide, boil quicklime or concentrated lye with ground sulphur as long as sulphur is dissolved.

TO ASSAY A CUPEL.—When it is desired to know how much silver has been absorbed by a cupel during cupellation, grind the saturated part of the cupel very fine, and scorify it with borax glass and a little granulated lead, or make a crucible fusion, using 25 grams of borax glass, 25 grams of soda and 1 gram of flour. Cupel the button.

*Formerly so called; now called thiosulphate, the name hyposulphite being applied to a different salt.

†With ores which contain lead, the work is much hastened by an addition of sodium carbonate to the leaching solution, which prevents the lead dissolving.

ASSAY BY AMALGAMATION.

TAKE any convenient quantity of the ore powder, add water enough to make a pulp, and heat it. If gold ore, add about 1-40th per cent of cyanide of potassium. If silver ore (not roasted), add 2 per cent of salt, and such other chemicals as may be desired, in such proportion as can be profitably used on the large scale. Agitate with pure quicksilver for several hours, in an iron mortar or a Buck's amalgamator with the muller slightly raised by a disc of iron placed on the top of the cone. Separate the pulp from the quicksilver by washing (panning). If gold ore, distil the quicksilver or dissolve it in *dilute* nitric acid; the gold will remain. It should be melted, either before the blowpipe or otherwise, to drive off any remaining quicksilver, which would cause spirting on attempting cupellation. If silver ore, strain the quicksilver through a piece of wet buckskin. (Twist the buckskin so as to press the quicksilver through.) Tie the amalgam in a bit of cotton cloth, put it in a dry-cup, and heat slowly to redness in the muffle. Wrap the metal, gold or silver, in sheet lead, cupel, part, weigh and calculate results by percentage.

ROASTED SILVER ORE REQUIRES NO CHEMICALS.

THE results obtained from gold rock in this way are too low, because some of the gold is dissolved in the parting from quicksilver by nitric acid. It is better to proceed as follows:—

After amalgamating, pan out very carefully into a dish or pan of water. Let the water settle, pour it into another vessel, leaving the ore behind. To the ore add some fresh quicksilver, and agitate for some time, then pour out again in the same water. Again settle, and pour off the clear water; dry and assay the tailings, also assay some of the original pulp. The difference between the two assays will show how much of the gold has been extracted.

A better result may be obtained by dissolving the cyanide of potassium in hot water, and dissolving in that solution about half as much red oxide of mercury, then adding it to the pulp, which, if acid to test-paper, should first be neutralized by means of lime or soda. The mercury should have a little zinc dissolved in it by the aid of heat.

TO FIND THE VALUE OF A SPECIMEN.

HANDSOME specimens of gold in quartz are in great demand. There are many rules for ascertaining the proportion of the gold in such specimens, all based on the different densities of the specimens as a whole, of the gold and of the quartz. The specific gravity of the gold and of the quartz is generally assumed, the former at from 17 to 19, the latter at 2.6; that of the specimen is found by weighing it in air and in water, and dividing its weight in air by the difference; in this case, the easiest rule to remember is this:—

Divide the specific gravity of the gold by that of the quartz and by that of the specimen. From the greater quotient subtract the lesser; the remainder is the *proportion* of gold. From the lesser quotient subtract 1; the remainder is the proportion of quartz.

Then, as the sum of these proportional quantities is to the proportion of gold, so is the weight of the specimen to the actual quantity of gold in it. Suppose a specimen weighs 32 ounces in air and 28 ounces in water; the difference is 4, and 32 divided by 4 gives 8, which is the specific gravity of the specimen. If the specific gravity of the gold is assumed to be 17, and that of the quartz 2.6, we have 17 divided by 2.6 gives 6.539, nearly, and 17 divided by 8 gives 2.125. Subtracting the lesser quotient from the greater leaves 4.414, and subtracting 1 from the lesser leaves 1.125, and the *proportion* is 4.414 of gold to 1.125 of quartz.

Adding these together, we have 5.539. Now it is a mere question in the rule of three. If 5.539 ounces of the specimen contain 4.414 ounces of gold, how much does the whole specimen, weighing 32 ounces, contain? Answer.—25.5 ounces. This is correct, provided the assumed specific gravities of the gold and gangue are correct, but if greater accuracy be desired, proceed thus:—

Weigh the specimen, a piece of the metal, and a piece of the gangue, each in air and in water. Divide the difference between the respective weights in air and in water by the weights in air. From the greater quotient subtract the next less, and from that the least. The first remainder is the *proportional* weight of the metal, the second is that of the gangue; the sum of these is that of the specimen. Having the actual weight of the specimen, that of the metal is easily found, as before, by the rule of three.

Suppose a specimen of native silver in spar weighs 84 pounds in air and 73.5 in water. A piece of the silver weighs 27 grains in air and 24 in water. A piece of the spar 20 in air and 12 in water, then—

Spar in air 20

Spar in water 12

—

Difference $8 \div 20 = 0.400$

Specimen in air . . . 84

Specimen in water 73.5

—

Difference $10.5 \div 84 = 0.125$

Silver in air27

Silver in water24

—

Difference $3 \div 27 = 0.111$ And $400 - 125 = 275 =$ proportion of silver“ $125 - 111 = 14 =$ “ spar

—

289= “ specimen

Then $289:275::84:79.93$ pounds of silver in specimen.

The difference between the weight in air and in water of a piece of rock, metal, etc., may be found in several ways, according to the facilities at hand, as follows:—

Weigh the object on scales or steelyard of suitable delicacy. Suspend the object by means of a hair, a fine thread, or a wire, according to its weight, under the pan of the scales or from the hook of the steelyard; submerge it in water, and again weigh it. Subtract the second weight from the first.*

Or, weigh the object; take a suitably-sized vessel full of water, or in which the water stands at a certain mark, and weigh that and the object together, if convenient, or, if not, weigh them separately, and add the results. Now remove some of the water, place the object in the vessel, replace so much of the water as to

*Some scales are provided with a hook, from which the object can be suspended above the pan. A little bench of sheet brass or tin is then placed across the pan, leaving the pan free to move beneath it, and a vessel containing water, in which the object is submerged, is placed on the bench.

raise it again to the mark, and weigh again. The difference between the last weight and the sum of the weights of the object and of the vessel of water is the weight of the water displaced by the object, which is equal to the difference of the weight in air and in water. This method is suitable for sand. Special bottles, called specific-gravity bottles, graduated to hold a certain weight of water, may be bought with counterpoise. Price, \$1.75 to \$3.50; capacity, 100 to 1,000 grains; also, 100 grams.

The weight of the object in air divided by its difference in water is the specific gravity. The difference divided by the weight in air is the specific displacement. From either of these the proportional quantities of two different substances composing a mixture can be determined by the rules given for the valuation of specimens.

For the purpose of this determination, when all of the substances are weighed in air and in water, it is not necessary that the water be pure or at standard temperature, as only relative displacements or specific gravities are required.

NOTE.—Let W. be weight of specimen in air, and let D. be difference of weight of specimen in air and water, then,

$$(W. \times \text{s. g. metal}) - (\text{s. g. metal} \times \text{s. g. gangue} \times D.)$$

$$\hline \text{s. g. metal} - \text{s. g. gangue.}$$

= weight of gold, and

$$(\text{s. g. metal} \times \text{s. g. gangue} \times D.) - (\text{s. g. gangue} \times W.)$$

$$\hline \text{s. g. metal} - \text{s. g. gangue}$$

= weight of gangue.

The determination of the gangue is useful as a check, and it will be observed that the subtrahend in the first equation is the minu-

end in the second, while the divisor is the same in each. Moreover, constants may be kept at hand for assumed s. g. of gold and gangue; then, at 17 and 2.6 respectively, s. g. gold \times s. g. gangue = 44.2, and s. g. gold — s. g. gangue = 14.4, so that the work in the first example given is only

$$\begin{array}{r}
 17 \times 32 = 544 \\
 44.2 \times 4 = 176.8 \\
 \hline
 14.4) 367.2 (25.5 \text{ oz. gold} \\
 \text{****} \\
 176.8 \\
 2.6 \times 32 = 83.2 \\
 \hline
 14.4) 93.6 (6.5 \text{ oz. gangue} \\
 \text{****}
 \end{array}$$

The following method is especially adapted to cases in which the s. g. of the metal and of the gangue are neither known nor assumed:—

Find the specific displacement, s. d., of the metal and of the gangue; also find D., as above, then

$$\begin{array}{r}
 (W. \times \text{s. d. gangue}) - D. \\
 \hline
 \text{s. d. gangue} - \text{s. d. metal}
 \end{array} = \text{weight of gold.}$$

And

$$\begin{array}{r}
 D. - (W. \times \text{s. d. metal}) \\
 \hline
 \text{s. d. gangue} - \text{s. d. metal}
 \end{array} = \text{weight of gangue.}$$

Taking our example of silver in spar:—

$$\begin{array}{r}
 84 \times .4 = 33.6 \\
 10.5 \\
 \hline
 .4 - .111 = .289) 23.1 (79.93 \text{ lbs. metal} \\
 \text{****}
 \end{array}$$

And

$$\begin{array}{r}
 10.5 \\
 84 \times .111 = 9.324 \\
 \hline
 .288)1.176(4.07 \text{ lbs. gangue} \\
 \text{****}
 \end{array}$$

As in the preceding example, the subtrahend of the one is the minuend of the other equation, and the divisor is the same for each; also, constants may be got for given s. d. of metal and gangue. In the preceding rule it is not necessary to calculate s. g. of specimen; in this it is not necessary to obtain s. d. of specimen. Displacement of small object can be got by means of a Mohr burette very easily.

TESTS FOR ORES, ETC.

SILVER, Ag.—Powder, mix about 50 mgs. with twice as much fine lead (free from silver), soda, and borax. Moisten with water, place in cavity scooped in piece of charcoal, smelt by blowpipe flame, cupel the lead, examine bead with lens, if large enough to handle, for gold. Or, powder, roast, boil in glass or earthen vessel with a clean strip of copper, bluestone, salt, and water; gives a white coat on the copper. (Nearly all silver ores will do so if boiled with bluestone and salt, without roasting.)

GOLD, Au.—Powder, roast if sulphurets are present, grind very fine, and wash in pan or horn; examine with lens; yellow particles not soluble in nitric acid.

COPPER, Cu.—Powder, moisten with salt brine, and throw into fire; an intensely blue flame. Or, moisten with muriatic acid, and direct blowpipe flame on it; the same. Or, roast, steep in ammonia; a blue solution. Or, boil in nitric acid and add ammonia; the same.*

LEAD, Pb.—Powder, mix about 50 mgs with 200 mgs. of soda, a little borax, and water to moisten; place on charcoal, and melt under blowpipe flame; gives a malleable, metallic globule, which, when melted on a cupel, gradually disappears, leaving a yellow stain and, perhaps, a bead of silver, or a coat on the charcoal

*Nickel also gives a blue solution, nearly like that of copper, with ammonia, but it does not give the blue flame.

which is dark lemon-yellow hot, sulphur-yellow cold; disappears on being heated, but *not touched*, by the blowpipe flame.

BISMUTH, Bi.—Powder, treat on charcoal same as for lead; coat darker than that of lead; coat heated but not touched by flame, melts into brown globule; globule of metal, if got, is brittle and reddish in color. It becomes covered by brown crust, which cracks during solidification, showing the bright metal, or the globule gives birth to a smaller one, which sprouts from its side and remains bright; best seen on a cupel. This is the only metal besides lead which can be cupelled alone.

ZINC, Zn.—Powder, throw into fire; brilliant white flame; treated on charcoal same as for lead, coat yellow; hot; white, cold; coat heated, but not touched, by flame, remains and is luminous; touched by flame, disappears; moistened by a drop of solution of cobalt nitrate and again heated to glowing, turns deep green when cold. To detect a trace of zinc, moisten the coal with a solution before producing the coat. Black zinc-blende is often mistaken for galena. The two may be distinguished by this infallible sign: The powder of galena is *black*, that of blende, *brown or yellow*.

TIN, Sn.—Powder, mix with soda (and cyanide of potassium if at hand) heat strongly on coal, covering with blowpipe flame; white metallic globules, which do not sink into a cupel when melted on it, but form a crust which is yellow hot. Nitric acid converts the globule into white powder, insoluble in water. Coat on coal similar to zinc, but closer to bead; does not dis-

appear when heated, whether touched by flame or not. Treated with cobalt solution, is bluish green when cold. Rare in United States.

ANTIMONY, Sb.—Powder treated as for tin; white coat on coal, extending a long way; easily driven about by flame; globule, if obtained, thrown on table while hot; rolls along, giving off dense fumes. Nitric acid converts the globule into white powder, which vanishes in smoke if heated on charcoal

BLACK OXIDE OF MANGANESE, MnO_2 .—Powder, add muriatic acid or sulphuric acid and salt; effervesces and smells of chlorine, which, if abundant, and the test is made in a test-tube or small bottle, may be seen as yellowish-green gas. Melt a trace with borax on platinum, beyond the point of the flames; an amethystine bead indicates manganese, and, as it evolves chlorine from muriatic acid, it is the dioxide, or "black oxide," and an *oxidizer*.

CHROMIUM (in chromates, etc.), Cr.—Powder, melt a very little with borax on charcoal *in* blowpipe flame; an emerald green glass.

IRON, Fe.—Powder, boil in muriatic acid and a drop of nitric acid; add a drop of solution of potassium ferrocyanide (yellow prussiate of potash); a deep blue color shows iron present. But treat another portion with muriatic acid alone, and add the ferrocyanide; if the same color is not now produced, the iron is not in a form to be an *oxidizer*.

TELLURIUM, Te.—Heat a fragment, or a little of the powder moistened, by blowpipe, on a piece of white

porcelain; moisten the still hot porcelain with strong sulphuric acid; a red color.

ARSENIC, As.—Powder; throw on live coals, or heat on charcoal, within the blowpipe flame; a garlic smell.

SELENIUM, Se.—Test as for arsenic; a smell of rotten horseradish.

SULPHUR, S.—Melt with soda on charcoal, then moisten and place on a piece of silver; a dark stain indicates *sulphur*.* But heat to redness in a scorifier or on an iron spoon, if a smell like that of burning matches is not perceptible, the sulphur is not in a form to be a *reducer*.

QUARTZ, or *hard silicate*, SiO_2 .—Not scratched by knife, not affected by acid; melted with 2 parts soda, froths and makes clear glass.

EARTHY CARBONATES (lime, CaO ; magnesia, MgO ; baryta, BaO).—Scratched by a knife, foam if touched by acid, dissolve with effervescence in muriatic acid to a colorless solution; burned in fire, become caustic quicklime, and no longer foam with acids.

EARTHY SULPHATES (gypsum, heavy spar, etc.).—Scratched by knife, not affected by acid; show sulphur by the test with silver, but give no smell on spoon.

NITRATES (Chile niter, KNO_3 , etc.).—Flash when heated on charcoal; dissolved in water with sulphuric acid and salt, can dissolve gold.

BORATES (borax, borate of lime, or cotton balls).—Moistened with glycerine and held in blowpipe flame, give green color to it. Or, treat with sulphuric acid

*Unless selenium be present, which also gives a stain.

in porcelain dish, add alcohol, and set fire to it; a green flame. No copper must be present in either test.

ALKALINE CARBONATE (of soda, Na_2CO_3 , or potash, K_2CO_3).—Dissolve in acids with effervescence, and do not lose this property by being melted; dissolved in water, and lime-water added, give a white precipitate. Solution turns reddened litmus-paper blue.

CLAY.—Breathed on, gives a peculiar smell, easily recognized when once known. If moistened, becomes plastic. If dry, sticks to the tongue.

BLOWPIPE.—Plain brass tube, 8 to 10 inches, 25 cents to 35 cents; with moisture-bulb, 8 to 10 inches, 50 cents; brass, with trumpet mouth-piece, condensing-chamber, and platinum jet, \$2.00; same, only all nickel plated, \$2.25; Fletcher's, with hot blast (the tube encircles the flame of the lamp, and becomes heated and dries the air), \$1.00.

By placing the tip within the flame of a candle or lamp, and blowing into the larger end, a pointed flame is produced. To make a cupel for use with the blow-pipe, scoop a circular cavity in a piece of charcoal, fill it with very fine moistened bone-ashes, press with a large bullet or other convex object, and dry. A button to be cupelled should be heated, but not touched, by the flame.

To make test-lead free from silver.—Dissolve acetate of lead in water, and add a piece of zinc. Wash the resulting lead with water and a little sudphuric acid, then with water. Dry and test for silver, which will not be found unless the zinc contained it, in which case the zinc is not fit.

A FEW SPECIAL MINERALS.

ARGENTITE, OR SILVER GLANCE (Ag_2S =Silver and Sulphur, 87 per cent silver).—Black, heavy, soft, malleable, sectile (can be cut in slices). Alone, BB* yields nearly pure silver.

CERARGYRITE, OR HORN SILVER ($AgCl$ =Silver and Chlorine, 75 per cent silver).—Pearly, yellowish, or greenish; exposed to light, turns dark; heavy, waxy, malleable, sectile. With soda BB yields pure silver. Iodide and bromide are very similar.

PYRARGYRITE, OR DARK RED SILVER (Ag_3S_3Sb =Silver, Sulphur, and Antimony).—Red to black, powder red, brittle, tender. BB with soda yields silver.

PROUSTITE, OR LIGHT RED SILVER (Ag_3S_3As =Silver, Sulphur and Arsenic).—Light red, powder red, brittle, tender. BB gives garlic odor, and with soda yields silver.

STEPHANITE, OR BRITTLE SILVER (Ag_5S_4Sb =Silver, Sulphur and Antimony).—Black, powder black, brittle, and very tender. BB with soda yields silver.

GALENA (PbS =Lead and Sulphur, 86 1-2 per cent lead).—Nearly black, shining, heavy, rather tender, usually, but not always, breaks in square blocks. The fine-grained kind generally carries antimony. BB with soda yields lead.

*BB means before blowpipe, on charcoal.

CERUSSITE, OR CARBONATE OF LEAD ($PbCO_3$ =*Lead Oxide and Carbonic Acid, 66 per cent lead*).—White, yellow, or nearly black, greasy looking, rather hard froths with acid. Alone, BB yields lead.

IRON PYRITES (FeS_2 =*Sulphur and Iron*).—Yellow to bronze, shining, not scratched by knife, sometimes strikes fire with steel. Alone BB gives abundant fumes of sulphur. When roasted, *before*, not *in*, the flame (or in the muffle) until it smells no more, is a red powder. Arsenical pyrites contain also arsenic; color, silver white. Often carry gold.

CHALCOPYRITE, OR COPPER PYRITES ($CuFeS_2$ =*Copper, Iron and Sulphur*).—Yellow shining, often iridescent on surface, scratched by knife; BB with soda (after roasting) gives grains of copper and iron. Purple copper is very similar. Sometimes carry silver.

CHALCOCITE, OR COPPER GLANCE (Cu_2S =*Copper and Sulphur*).—Nearly black, rather soft sectile. BB with soda (after roasting), yields copper. This mineral is sometimes mistaken for silver glance. The two may occur combined.

GRAY COPPER (*Copper, Zinc, Antimony, and Arsenic, and sometimes Silver and Mercury*).—Dark gray. (See tests for silver, etc.)

MALACHITE, OR COPPER CARBONATES (Cu_2CO_4 =*Copper Oxide and Carbonic Acid*).—Bright blue or green, often crystallized, froth with acid, dissolve in ammonia with beautiful blue color. BB with soda yield copper.

CUPRITE, OR RED COPPER (Cu_2O =*Copper and Oxygen*).—Deep red, tender, does not froth with acid, dis-

solves in ammonia, and the solution turns blue by exposure. BB with soda yields copper.

SPHALERITE, OR ZINC-BLENDE (ZnS =*Zinc and Sulphur*).—Black, red, yellow, green, or colorless (rarely), powder always light colored. (See test for zinc and sulphur.)

STIBNITE, OR SULPHURET OF ANTIMONY (Sb_2S_3 =*Antimony and Sulphur*).—Gray, shining, usually fibrous or in stars, tender, and will melt in candle-flame. Alone, BB flies away in smoke, leaving white coat on coal. (See test.)

SOLUBILITY OF METALS.

THE following-named metals act as stated in the different liquids with the aid of heat. It must be understood that not the *ores* of metals, but the metals themselves, as melted out by blowpipe or otherwise, are meant:—

In moderately strong nitric acid:—

<i>Dissolve,</i>	<i>Not,</i>
Silver, copper, iron, lead, bismuth, zinc, mercury.	Gold, Platinum. Tin and antimony are converted into white powder.

In strong sulphuric acid:—

<i>Dissolve,</i>	<i>Not,</i>
Silver, copper, bismuth, zinc, tin, mercury, antimony. Lead is converted into sulphate, and dissolved if enough acid is present.	Gold, platinum, iron. Lead is converted into sulphate, and partly dissolved.

In dilute sulphuric acid:—

<i>Dissolve,</i>	<i>Not,</i>
Iron, zinc, tin.	Gold, platinum, silver, copper, lead, bismuth, mercury.

In hydrochloric acid:—

Dissolve,

Iron, zinc, bismuth, antimony in powder. Tin slowly in an abundance of strong acid.

Not,

Gold, platinum, silver, copper (unless in very fine powder), lead, mercury.

In mixed nitric and hydrochloric acids:—

Dissolve,

Gold, platinum, copper, iron, bismuth, lead (with water), zinc. Tin and antimony with excess of hydrochloric acid.

Silver and mercury are acted on, but not dissolved. Antimony remains as a white powder if nitric acid is in excess.

In solution of caustic potash, zinc and tin dissolve, also aluminum.

SUBSTITUTES AND EXPEDIENTS.

If nitric acid is not at hand, use instead a solution of niter to which some sulphuric acid is added; this must be tested for chlorine, as directed for nitric acid, before being used for parting. For hydrochloric acid, take a solution of common salt and add sulphuric acid to it.

If litharge can not be conveniently got, ground galena may be used in its place in crucible assays by the second system; it should contain no gold and but little silver, and the assays must be corrected for that which it does contain; the weight used should be at least equal to that of the ore, unless the latter contains lead, when less will answer. Lead may be obtained from galena by fusion in a crucible with pieces of iron, iron ore, or soda; it may be granulated by means of a rasp.

Ground glass, mixed with a little soda, will answer in place of borax.

The baking soda sold in the stores will serve as well as any for making assays; also soda ash.

Niter may be replaced in ore assays by manganese black oxide, or iron red oxide, if a plenty of borax or glass be used.

Bone ashes may be made by burning and grinding bones; the soft bone from the horns of cattle is best.

A common table knife will answer for a spatula.

A coarse sieve may be readily made from a tin pan by suitably puncturing its bottom; a fine one by stretching a piece of gauze on a frame or hoop of wood or metal.

A flat rock will answer for a mortar or grinding-plate, a large pebble or small boulder for a pestle or muller.

A crucible laid on its side will serve as a muffle. A quicksilver flask, of which one end has been removed, is better; a hole should be made in the rear end of the flask.

A furnace may be built of rocks and mud, or of mud alone, or *adobes*. A blacksmith's forge may be used for both melting and cupelling, the cupel being placed on a piece of brick or iron in the midst of the fire, or in any kind of muffle.

A scorifier or a roasting-dish may be formed by hand from good white clay, or carved from soap-stone.

Cupels may be made by pressing moistened bone ashes into suitably-sized rings of tin, sheet or hoop iron; the cupels so made are used with the rings still on them.

Pincettes may be made by bending a strip of sheet metal pointed at both ends, or, for coarser ones, a piece of stout wire, the ends flattened by filing.

For an anvil, any flat, smooth piece of iron will do; the head of an ax or hatchet struck into a block.

A strip of paper folded lengthwise forms as good a test-tube holder as need be, by being doubled, the tube in the loop and the ends held in the hand.

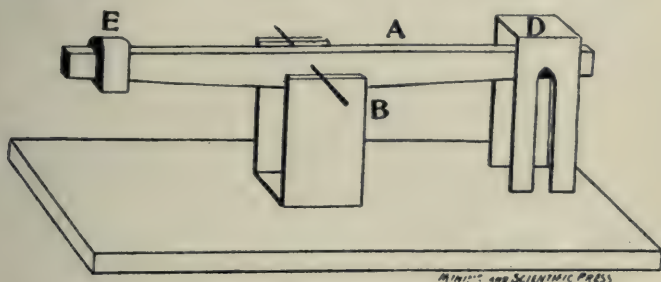
A teacup or part of one will serve for parting in, being warmed with care. A Chinese small porcelain basin is better, and is useful in other ways.

A water-bath is any vessel containing boiling water on which a pan or dish can be placed as a lid.

A SIMPLE ASSAY BALANCE.

A BALANCE for weighing pulp, buttons, etc., and one for beads may be made as shown in the cut.

The beam A is of wood; the support B and pan D of tin; the counterpoise E of lead. Two needles passed through the beam form the points of suspension. A



second and lighter rider or counterpoise will be found useful for fine weighing; it may be made of wire or paper.

The center of gravity of the beam must be neither too high nor too low; if too low, the instrument will not show plainly a sufficiently small difference of weight; if too high, the beam, when nearly equally loaded on the two ends, will fall to either side and there remain; it will be top-heavy, and will not swing; it must be adjusted by cutting away the upper or lower edge, or by loading either as may be required.

Two such scales will be required, one of about the

size shown in the illustration, for weighing beads, and one much larger, for pulp, fluxes, buttons of lead or copper, etc.

It will be found convenient to arrange a support under the end E of the beam, in order to limit its range of movement. To weigh a bead or button, put it on the pan, and remove the riders until the beam is exactly balanced, then move the bead, and put weights on the pan until the counterpoise is again balanced; the weights required are equal to the bead or button. A well-made small scale will work correctly to 1-100 grain or less.

To weigh the pulp for an assay, place the proper weight on the pan, and adjust the counterpoise to balance it, then remove the weight, and put pulp on the pan until it again balances; the weight of pulp is equal to that which it replaces. Lift the pan off the beam, and pour the pulp into the crucible.

A cheap lens may be made by placing a drop of water on a clean, dry piece of window-glass.

ASSAY TABLE.

FOR TWO HUNDRED AND FORTY GRAINS OF ORE.

BEAD POINTS.	OUNCES IN A TON OF THE ORE.	VALUE (in dollars) OF SILVER.	VALUE (in dollars) OF GOLD.
	<i>u. t. h. th.</i>	<i>u. t. h. th.</i>	<i>u. t. h. th.</i>
1	1215278	1571261	25122067
2	2430556	3142523	50244134
3	3645834	4713784	75366202
4	4861112	6285045	<i>u. t. h. th.</i> 100488269
5	6076390	7856307	125610336
6	7291668	9427568	150732403
7	8506946	<i>u. t. h. th.</i> 10998830	175854470
8	9722224	12570091	200976537
9	<i>u. t. h. th.</i> 10937502	14141352	226098605

Find the right-hand figure of bead-weight in the column of "Bead Points," and the figures for ounces or value under the corresponding head. Set the figures down, or as many of them as may be wished, pointing off:—

For tenths *u.* etc.

For units all to the right of *u.*

For tens " " *t.*

For hundreds " " *h.*

For thousands " " *th.*

Proceed then with the next figure, setting down this value with the decimal point under that of the first, and so on, then add all together. Example: A bead equals 42.7, required the ounces in a ton:—

7 tenths .....	.85
2—units	2.43
4—tens	48.61
<hr/>	<hr/>
42.7	51.89 ounces.

It will be found convenient to take a pointer (a dry pen or a pencil), and, when inspecting the table, place it between the figures where the decimal point will fall, and then read and transcribe the value. In this way the superfluous figures to the right, say, beyond two or three places of decimals, need not be noticed, and all risk of confusion will be avoided. A little practise will be needed to give facility.

ASSAY TABLE.

FOR TWENTY GRAMS OF ORE.

BEAD POINTS.	OUNCES IN A TON OF THE ORE.	VALUE IN GOLD. (Dollars.)
	<i>u. t. h. th.</i>	<i>u. t. h. th.</i>
1	145833	3014642
2	291667	6029284
3	437500	9043926
4	583333	<i>u. t. h. th.</i> 12059567
5	729167	15073209
6	875000	18087851
7	<i>u. t. h. th.</i> 1020833	21102493
8	1166667	24117135
9	1312500	27131777

This table is used in the same manner as the preceding one; there is, also, another use to which it can be put, which the author believes to have been first noticed by himself; it is finding the equivalent in troy ounces of any number of pounds and decimals of a pound avoirdupois. Multiply the pounds by 10, consider the product as milligrams of metal got from a 20-gram assay, and find by the table the corresponding number of ounces. To find the value of a bar of which the weight is given in pounds,

multiply the pounds by the fineness and that product by 10; consider the last product as milligrams of gold or silver, as the case may be, and take the values from the table as though for an ore assay.

ASSAY TABLE.

FOR ONE ASSAY TON OF ORE.

OUNCES.	GOLD—VALUE.	SILVER—VALUE.
1	^{u. t. h. th.} \$ 2067183	^{u. t. h. th.} \$ 1292929
2	4132367	2585858
3	6201550	3878788
4	8278734	5171717
5	^{u. t. h. th.} 10335917	6464646
6	12403101	7757576
7	14470284	9050505
8	16537468	^{u. t. h. th.} 10343434
9	18604651	11636364

This table is used in the same way as the others, but as the ounces per ton are got at once from the bead-weight, only values per ton are required; it is also applicable to finding the value of bars, and the value per ounce of bullion of any given fineness.

To find the value of any number of ounces of bullion of any fineness, multiply the weight in troy ounces by the fineness; the product is the weight of the pure metal. Find the value of the pure metal from the table.

Example: A silver bar weighs 1,642 ounces, and is .840 fine, what is its value?

$1642 \times .840 = 1379.28$ ounces of pure silver in the bar :—
Then, from the table,

1,000	oz. =	.....	\$1,292.93
300	“ =	.....	387.88
70	“ =	.....	90.50
9	“ =	.....	11.63
0.2	“ =	.....	0.26
0.08	“ =	.....	0.01

*1,379.28 oz. =\$1,783.21

One ounce of bullion one thousand fine is of the same value as one thousand ounces one fine; or 372 ounces 1,000 fine = 1,000, .372 fine.

To find the value of one ounce of bullion of any fineness:—

Consider the “points” of fineness as so many ounces 1,000 fine, and find the value of that quantity from the table. Divide by 1,000 (move the decimal point); the quotient will be the value of one ounce at the given fineness.

Example: What is the value per ounce of silver bullion .840 fine?

$$\begin{array}{rcl} 800 \text{ oz. } 1,000 \text{ fine} & = & \$1,034.34 \\ 40 \text{ “ “ “} & = & 51.72 \end{array}$$

\$1,086.06

And $\$1,086.06 \div 1,000 = \1.086 per oz.

All these calculations are made on the old basis of

\$1.2929 per ounce for silver; the values found must be corrected to correspond with the commercial value. This, however, is not the case with gold, which is always reckoned at \$20.67 per ounce of pure metal, and the value of a gold bar can be got from the table in the same way as that of the silver bar.

The following tables will be convenient to those who may wish to make a full set of Assay Ton weights to go with either grain or gram assay-ounce weights. The various pieces may be made of any convenient metal, as lead, brass, or silver. Below 0.01 A. T. they are best made of aluminum, because that metal, being light, allows them to be of good size; but these lower fractions will not be required in weighing fluxes, flour, etc., so that they may be omitted, unless it is intended to weigh the prills of metal from lead, tin, bismuth, etc., assays with them. All of the weights above 0.01 A. T. may be adjusted by means of the pulp-balance; below that, the assay scales should be used. To make a weight, cut a piece of metal so that it is a little too heavy, and then trim it carefully by clipping and filing until it is of the right weight. Begin with the larger ones, then, if, by accident, you make a piece too light, it may be used for the next smaller. By combining the pieces, any fraction of an A. T. can be weighed to 1-100, corresponding to 20 pounds in the real ton, or with the full set, to 1-1000, corresponding to 2 pounds.

GRAIN SYSTEM.

ONE ONE-HUNDREDTH GRAIN IS ONE ASSAY OUNCE.

1	A. T. CONTAINS.....	291.667	GRAMS
0.5	" " "	145.833	"
0.2	" " "	58.333	"
0.2	" " "	58.333	"
0.1	" " "	29.167	"
0.05	" " "	14.583	"
0.02	" " "	5.833	"
0.02	" " "	5.833	"
0.01	" " "	2.917	"
0.005	" " "	1.458	"
0.002	" " "	0.583	"
0.002	" " "	0.583	"
0.001	" " "	0.292	"

GRAM SYSTEM.

ONE MILLIGRAM IS ONE ASSAY OUNCE.

1	A. T. CONTAINS.....	29.1667	GRAMS
0.5	" " "	14.5833	"
0.2	" " "	5.8333	"
0.2	" " "	5.8333	"
0.1	" " "	2.9167	"
0.05	" " "	1.4583	"
0.02	" " "	0.5833	"
0.02	" " "	0.5833	"
0.01	" " "	0.2917	"
0.005	" " "	0.1458	"
0.002	" " "	0.0583	"
0.002	" " "	0.0583	"
0.001	" " "	0.0292	"

In working with the gram system, the operator must not omit to observe whether his assay-weights, with which the beads are to be weighed, are 1 gram=1,000 in which case the unit is a milligram, or an Assay Ounce with reference to the A. T., or $\frac{1}{2}$ gram=1,000, when the unit is a half milligram, or a half Assay Ounce with reference to the A. T., and *therefore an Assay Ounce to the half A. T.*

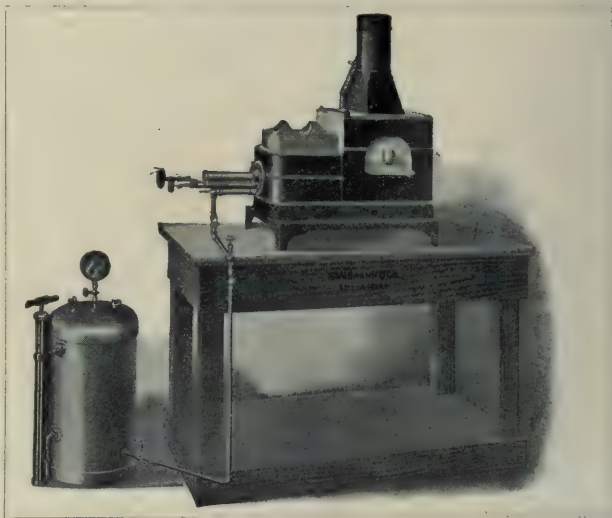
In the first case, the bead-weight as obtained from the

assay-balance is the number of ounces in a ton if an A. T. of ore was used; in the second case, the bead-weight is the number of half ounces in a ton if an A. T. of ore was taken, hence must be divided by 2 for the ounces, but it is the number of ounces to the ton *if a half A. T. of ore was used*.

TABLE OF VALUES OF GOLD

WEIGHT	OF GOLD IS WORTH
1 grain Troy	\$0.0430
1 gram=15.43 grains Troy.....	0.6646
1 pennyweight Troy=24 grains Troy.....	1.0335
1 ounce Troy=20 pennyweights Troy=480 grains Troy=31.10 grams.....	20.6718
1 ounce Avoirdupois=437½ grains Troy= 28.35 grams.....	18.8415
1 pound Troy=12 ounces Troy=240 penny- weights Troy=5,760 grains Troy= 373.24 grams.....	248.0620
1 pound Avoirdupois=16 ounces Avoirdu- pois=7,000 grains Troy=453.59 grams..	301.4642
1 ton Avoir.=2,000 pounds Avoir.=(29.166 ounces Troy; 32,000 ounces Avoir.)= 14,000,000 grains Troy.....	602,928.4660

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BRANCH OFFICES:

NEW YORK, 42 BROADWAY
CHICAGO, 1362 MONADNOCK BLOCK
DENVER, 420 MCPHEE BUILDING

Published by the Dewey Publishing Company

\$3 PER YEAR. FIFTY-TWO ISSUES
(ADD \$2 FOR FOREIGN POSTAGE)

ESTABLISHED
MAY 24, 1860

SAN FRANCISCO, CALIFORNIA, U. S. A.

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BY

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